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DETERMINATION OF ESTIMATED MEAN MINE WATER QUANTITY AND QUALITY FROM IMPERFECT DATA AND HISTORICAL RECORDS

Environmental Quality Systems, Incorporated

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Appalachian Regional Commission

January 1973

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This report is one of a series dealing with different aspects of environmental pollution in the Monongahela River Basin. The purpose of the study on which this report is based was to develop a methodology determining thie increase or decrease and the sources of pollution when complete data is not available. Special attention was given to acid mine drainage.

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Prepared For

THE APPALACHIAN REGIONAL COMMISSION

Prepared By

ENVIRONMENTAL QUALITY SYSTEMS, INC.

WASHINGTON, D.C.

JANUARY 1973

PREFACE

This study is one of a series of reports being prepared for the Appalachian Regional Commission for the development of an overall environmental pollution abatement plan for the Monongahela River Basin with special attention to mine drainage. The Basin is an 18-county area encompassing parts of Appalachian West Virginia, Pennsylvania and Maryland.

These studies are being performed under an agreement between the Environmental Protection Agency and the Commission and are part of a larger EPA effort to deal with elimination and control of mine drainage within the watershed. The Commission's major responsibility in this interagency effort is to evaluate the economic development impacts of mine drainage and other pollution abatement which will include for planning purposes those engineering studies necessary to determine cost effectiveness among possible alternative approaches and to assess the full range of activities required to improve the environment within the Basin consistent with water and land use objectives. It is felt that if pollutants and other environmentally degrading problems can be alleviated, other public and private investments will provide greater opportunities to improve the economy of the Basin. The results of these studies then should suggest courses of action for selecting priorities for environmental and associated projects to Federal, State, and local decision-makers and the private sector as well as clarifying the Basin's potential for economic development.

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BOUND SEPARATELY:

VOLUME	
II	RESULTS OF STANDARD MINE DATA ANALYSES
III	(IN 4 SECTIONS) SYNTHESIZED NSS TIME-LOAD PROFILES
IV	SOURCE RANKINGS BY ACIDITY LOAD

Note: Because of their size, Volumes II, III and IV, which consist of computer printouts, have been bound separately and have been placed for reference at the following depository libraries:

(1) Environmental Protection Agency offices at:
- Wheeling, West Virginia
- Philadelphia, Pennsylvania (Region III)

(2) U.S. Army Corps of Engineers, Pittsburgh, Pennsylvania

(3) Bituminous Coal Research, Monroeville, Pennsylvania

(4) State Water Quality Agency offices at:
- Harrisburg, Pennsylvania (DER)
- Charleston, West Virginia (DNR)
- Annapolis, Maryland (DNR)

(5) ORSANCO, Cincinnati, Ohio

(6) ORBC, Cincinnati, Ohio

(7) Appalachian Regional Commission, Washington, D.C. (2)

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CHAPTER I

INTRODUCTION

A technical committee was convened to analyze available data and report on the results of its analysis to the Enforcement Conference on the Mononganela River and its tributaries. A report was prepared (2) and submitted to the Enforcement Conference during 1971. One of the recommendations of the technical committee states in part: "Develop methods to assign priorities to areas or subbasins that are to receive abatement measures. These methods shall be based on sound technical principles consistent with attainment of the established water quality standards."

Other recommendations were associated with establishing a priority system for pollution abatement and economic recovery of the Monongahela River Basin. The Appalachian Regional Commission is developing such a priority analysis system at the present time. The work reported on herein is a portion of the overall Appalachian Regional Commission program to develop priorities within the Monongahela River Basin.

The effort described in this report was performed between June and November 1972. The objective was to construct a technique which could be used to rank the 30 subbasins of the Monongahela Basin in the order in which they contribute to the total pollution load of the Basin, the greatest to the least.

A mathematical modelling technique was developed and applied to the available data record for the Basin after a complete search was made to accumulate data from the technical literature and other sources, including that stored on magnetic tapes and in the possession of the Environmental Protection Agency and the Appalachian Regional Commission.

The mathematical technique and the results of the analysis are presented in this report which consists of four volumes, bound separately in seven parts. Volume III contains four sections bound separately. Volumes II, III and IV consist entirely of computer printout. Volume I contains the descriptive material, description of the mathematical technique, results, and summaries of results of the remaining volumes.

Data and information used in the preparation of the report and in the analyses were derived from many sources. Particular acknowledgment is due to the staff of the Appalachian Regional Commission, particularly Dr. David Maneval, the staff of the Mine Drainage Section of the National Environmental Research Center of the Environmental Protection Agency at Cincinnati, Ohio, particularly Mr. Ronald Hill and Mr. John

Martin, and the staff of the Bituminous Coal Research Library. Dr. Charles R. Jenkins of the University of West Virginia assisted in the accumulation of data.

CHAPTER II

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. A mathematical technique has been developed which utilizes a ratio of vectors technique to analyze available mine drainage data records. It was used to analyze the records which exist for the Monongahela River Basin. The model is relatively easy to program, straightforward in its application to available data, and is conservative of machine time.
2. The month-to-month variability of pollutant concentrations in mine drainages from a given source tends to be small while that of flow is marked. The variability of flow is the dominant factor in determining the variability of pollutant load.
3. The pollution load patterns of the non-standard sources (NSS) exhibited the same characteristics as did the selected standard mines (SM).
4. The pollutant loads observed in the various Monongahela subbasins are generally dominated by relatively few large sources within each subbasin. Less than 37 percent of the draining sources in the Monongahela River Basin contribute about 98 percent of the pollution load from acid mine drainage.

5. The data and results presented in this report may be used to design a priority format for an acid mine drainage water pollution control program on the basis of:

   A. individual mines,

   B. individual subbasins within the Monongahela Basin, and,

   C. the Monongahela Basin as compared to other river basins in the United States.

6. As nearly as can be determined, this report contains all of the raw data which exists for the 14 standard mines which were used in the analysis and for all of the draining sources (2,298) of mine drainage in the Monongahela River Basin, for the first time in one place.

7. The 30 subbasins within the Monongahela River Basin have been ranked in accordance with the production of pollution load on the basis of acidity, the greatest to the least. The results of this analysis are presented in Chapter IV. The following subbasins are the five largest contributors of pollution load on the basis of acidity in the order given:

   1. # 24 Sewickley Creek Subbasin
   2. # 2 Redstone and Dunlap Creeks Subbasin
   3. # 6 Upper Monongahela River Subbasin
   4. # 5 Dunkard Creek Subbasin
   5. # 4 Middle Monongahela Subbasin

8. Analysis of the data available for the 14 mines classified as "Standard Mines" for purposes of this analysis revealed the following:

   A. Concentration profiles remain relatively constant with time (are represented by relatively flat curves).

   B. It appears that mine drainage discharges can be represented by a relatively stable relationship of rankings between various pollutants: e.g., if iron concentration generally remains higher than sulfate during one month, it will generally do so for the period of the whole cyclical year.

   C. The pollutant time-load vectors for standard mines appear to fall into identifiable families of curves. This suggests the possibility that analysis of only one or two parameters, e.g., flow and acidity, could be used to project the whole range of pollutant time-load vectors.

9. The overall analysis of the data suggests that the high degree of variability and unpredictability related to acid mine drainage discharges may, in fact, be less variable and more predictable than has been felt in the past.

10. The analysis resulted in a ranking of subbasins and also in a ranking of individual mine drainage sources within each subbasin.

RECOMMENDATIONS

1. It should be stated that since the verification of the model procedure has not been completely performed as a result of this effort, and since to the present time the technique appears to be very successful, that it would be desirable to perform similar analyses with regard to the pollutants and concentration and flow relationships in streams. Further, it would be appropriate to relate the time-load relationship derived as described in this report for all sources within a subbasin, to the time-load relationships derived on the basis of stream data. This effort would close the loop and would substantially verify the techniques developed and described herein. The data required to perform such an analysis is available in the STORET data storage and retrieval system operated by the Environmental Protection Agency.

2. It would appear to be worthwhile to pursue a program directed at discovering and finding explicit mathematical relationships for mine drainage discharges.

2. (Continued)

Assuming such relationships could be found, they would become extremely important and useful to designers of acid mine drainage control systems and treatment plants, as well as to planning and budget agencies.

3. Similar analyses using the techniques described can and should be performed for other river basins within Appalachia. Such an effort would result in a priority scheme, from a pollution point of view only, which could be used to develop programs throughout the Appalachian region.

CHAPTER III

THE MATHEMATICAL PROCEDURE FOR ANALYZING INCOMPLETE ACID MINE DRAINAGE CONTAMINATION DATA

Definitions

Acid Mine Drainage Contamination (AMDC). For purposes of this analysis Acid Mine Drainage Contamination is defined as the presence of any or all of the following pollutants: (1) Acidity; (2) Iron; (3) pH; (4) Hardness; (5) Alkalinity; (6) Sulphate; (7) Total Iron; (8) Total Manganese; and (9) Total Aluminum.

Concentration of a particular AMDC pollutant is an indication of the intensity of that pollutant in a unit of volume and is expressed in milligrams per liter (mg/l). Total load, on the other hand, is a measure of the total weight of an AMDC pollutant passing a certain point along the course of a stream during a unit of time. Total load is generally expressed in pounds of pollutant per day.

There is a relationship between concentration and total load. The connecting factor is the quantity of water flowing past a geographical location. That is, if we know the concentration of a particular pollutant in the water flowing past a geographical point and the quantity of water flowing past that point, we can calculate the total load of that contaminant flowing past the point in question. The relationship may be expressed as follows:

(1) $$L = 0.1905QX$$

Where: L = Total load (lbs/day)
X = Concentration of pollutant (mg/l)
Q = Flow of water (liters/sec)
.1905 = A constant for converting mg/sec to lbs/day

The Standard Mine (SM). For purposes of this analysis certain mine openings have been designated as Standard Mines. The criteria for selection as an SM were: (1) that sufficient data were available to establish the AMDC load contribution by that mine opening over time; and (2) that the AMDC time-load patterns of each SM were thought to be characteristics of a number of mine openings. A list of the 14 SM's selected for use in this study is included as Appendix I.

Non Standard Source (NSS). A Non Standard Source is an AMDC contributing mine opening located in the Monongahela River Basin other than an SM. There are several thousand such NSS located in the basin, but data specifying the nature and quantity of AMDC generated by these mine openings is sparse.

Cyclical Month. A cyclical month identifies a calendar month without regard to year. The term is used to identify AMDC behavior by month independent of year. Thus, the February AMDC behavior of a discharge during one year is likely to be typical of the February AMDC behavior of that discharge during some other year. AMDC characteristics of a stream during a cyclical month were estimated by averaging data for that month over all years for which data were available.

Cyclical Year. A cyclical year is a representative year comprised of cyclical months.

Time-Load Vector. For purposes of this analysis, a time-load vector for a particular pollutant and source is defined as a vector whose elements are ratios of all possible unique cyclical monthly loads. To illustrate, suppose that for a given pollutant and source, the cyclical monthly loads for each of the twelve months are represented by the abbreviations:

[JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP,
OCT, NOV, DEC.]

Then the time-load vector for this source and pollutant consists of the ratios:

[FEB/JAN, MAR/JAN, APR/JAN, ---,
DEC/JAN, MAR/FEB, APR/FEB, ---,
DEC/FEB, ---, DEC/NOV]

It follows that a complete time-load vector consists of 66 elements. A time-load vector is unitless since it is an array of ratios. Also, a time-load vector is not necessarily unique to a source. That is, two sources whose actual AMDL loads over a cyclical year differ widely, could possess the same time-load vector.

Time-Load Profile. A time-load profile for a given pollutant and source is a vector whose elements are the cyclical month AMDC loads. Using the abbreviations from the previous example, the illustrative time-load profile would be:

[JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP,
OCT, NOV, DEC.]

Note that the magnitude of the load for one cyclical month plus the appropriate time-load vector are sufficient to define the time-load profile for a particular source and pollutant.

Assumptions

(1) That AMDC load is conserved as it flows downstream.

(2) That immediate mixing of AMDC takes place at its source so that the composition of sample flow is homogenous in a plane perpendicular to the direction of flow.

(3) That the true time-load vector for any NSS and pollutant is characterized by a time-load vector of one of the 14 SM's for that pollutant.

(4) That AMDC load data for a given NSS and pollutant is the best indicator of the magnitude of load discharged by that NSS.

Approach

Given the above definitions and assumptions, the approach employed in analyzing the AMDC data was to first analyze the data available for each SM and pollutant to determine the cyclical patterns and magnitudes of AMDC concentration and load. The mean concentration and mean load for each pollutant and SM for each cyclical month was estimated by averaging all available data for each month. The sample variance and standard deviation within each cyclical month was also calculated for each pollutant and SM. This provided an estimate of the variation of concentration and load that might be expected within a cyclical month and provided a feel for the stability of the sample means. Next, estimates of covariance and coefficients of correlation between all pairs of pollutants within each SM and cyclical month were calculated. This provided an indication of the degree of inter-relationship existing between the concentrations and loads of the various pollutants being discharged by a particular source. If a high degree of correlation between pollutants could be established, then some valid inferences can be made as to the concentration and load of one pollutant, given measures of concentration and load of some other pollutant.

No attempt was made to estimate variance between the years represented in the data base because, even for the SM's, the data base was not sufficiently broad or consistant to support such an analysis.

The mean load calculations for the SM's exhibited time-load profiles similar to those shown schematically in Figure 1. The next phases of the analysis involved combining the NSS data with that of the SM's to synthetically generate similar time-load profiles for each pollutant and NSS for which data were available. The first step in this process was, for each NSS pollutant on which data were available, to select the SM time-load vector for that pollutant that best fit the NSS data. Once this was accomplished, the load magnitude of the selected SM time-load vector was adjusted so as to pass through the NSS data points with the least squared error. This second step produces the final synthetic time-load profile for the pollutant and NSS in question. It should be noted at this point that the procedure described above may lead to selection of time-load vectors from a number of different SM's as being representative of the different pollutants discharged by one NSS. For example, the same NSS may lead to an iron time-load vector selection from Florence I, and an acidity time-load vector from GTO6-01.

Statistical Estimation

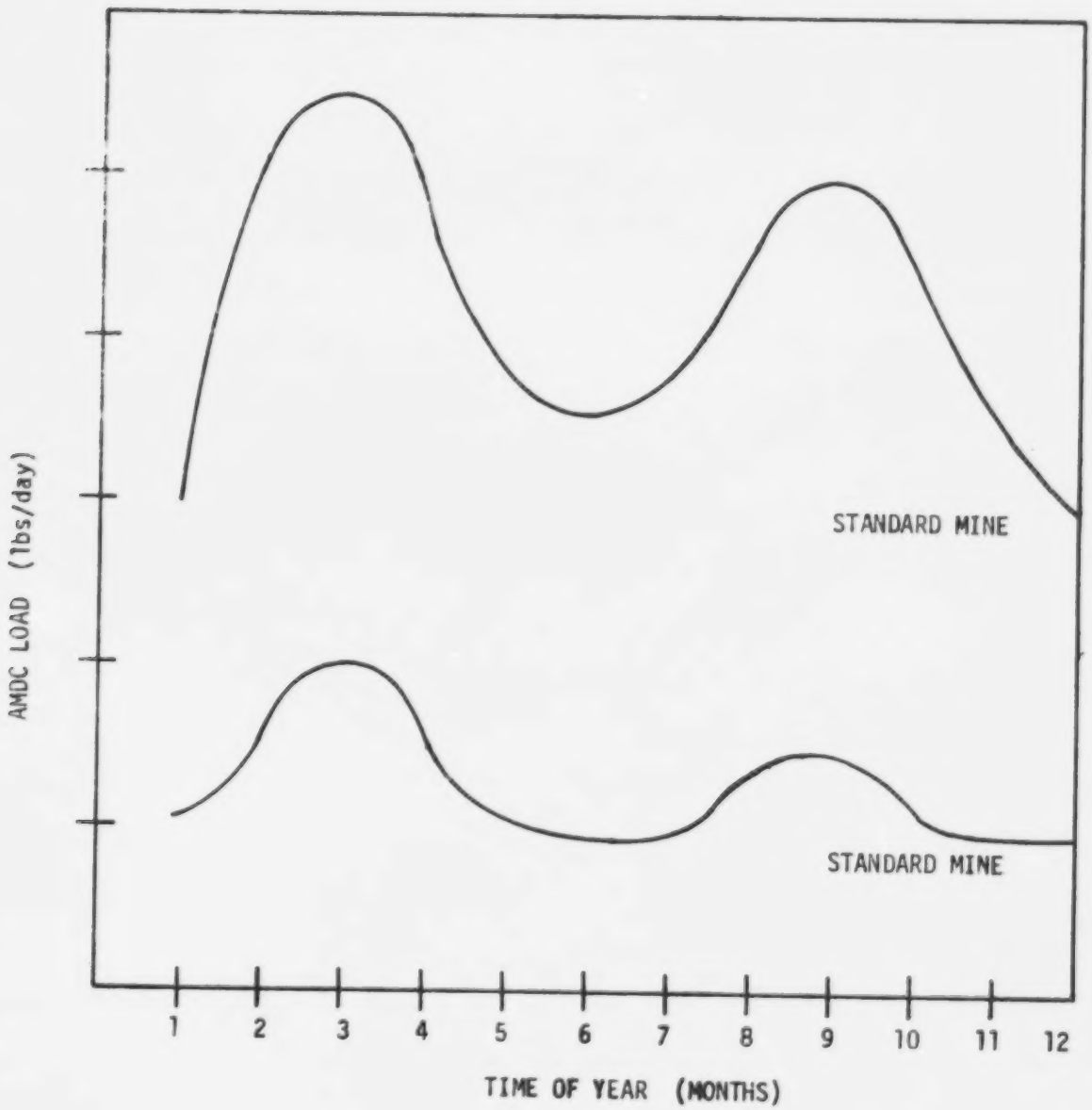
This section describes the statistical estimation formulae used in calculating sample means, variances, standard deviations, covariances and coefficients of correlation. Their derivations may be found in any standard text on mathematical statistics.

Clearly, the three components of equation (1) are functions of the pollutant involved, the source, and the period of time considered. Thus, if we define the variables:

u = the pollutant involved
v = the mine opening identity
t = the time period of consideration (cyclical month),

FIGURE 1

TYPICAL STANDARD MINE LOAD PATTERNS (SCHEMATIC)



and use the symbology of equation (1) (L=load, Q=flow, X=concentration), we can express this functional relationship in notational form as;

$$L = L(u,v,t)$$
$$Q = Q(v,t)$$
$$X = X(u,v,t)$$

It follows that the variable u ranges over the mine drainage pollutants enumerated previously, the variable v ranges over all of the mine openings considered in the study, and the variable t ranges over all of the time intervals considered. With regard to the time variable, t, the cyclical month was chosen as the basic interval of time used in the treatment of AMDC data.

Letting the symbol $X(u,v,t)_i$ represent the ith reading of AMDC concentration of pollutant u, at opening v, taken during month t, the cyclical monthly mean concentration is calculated as:

(2) $$\overline{X}(u,v,t) = 1/n \sum_{i=1}^{n} X(u,v,t)_i$$

Where: n = the number of readings recorded during cyclical month t.

In like manner, cyclical monthly mean flow and load are calculated as:

(3) $$\overline{Q}(v,t) = 1/n \sum_{i=1}^{n} Q(v,t)_i$$

(4) $$\overline{L}(u,v,t) = 1/n \sum_{i=1}^{n} Q(v,t)_i \; X(u,v,t)_i$$

These calculations were made for each pollutant for the fourteen selected SM's.

Monthly variances $\sigma^2_{X(u,v,t)}$, $\sigma^2_{Q(v,t)}$, $\sigma^2_{L(u,v,t)}$, and standard deviations $\sigma_{X(u,v,t)}$, $\sigma_{Q(v,t)}$, $\sigma_{L(u,v,t)}$, were calculated for each SM in the following manner:

(5) $$\sigma^2_{X(u,v,t)} = [1/(n-1)] \sum_{i=1}^{n} [X(u,v,t)_i - \overline{X}(u,v,t)]^2$$

(6) $$\sigma^2_{Q(v,t)} = [1/(n-1)] \sum_{i=1}^{n} [Q(v,t)_i - \overline{Q}(v,t)]^2$$

(7) $$\sigma^2_{L(u,v,t)} = [1/(n-1)] \sum_{i=1}^{n} [L(u,v,t)_i - \overline{L}(u,v,t)]^2$$

(8) $$\sigma_{X(u,v,t)} = \sqrt{\sigma^2_{X(u,v,t)}}$$

(9) $$\sigma_{Q(v,t)} = \sqrt{\sigma^2_{Q(v,t)}}$$

(10) $$\sigma_{L(u,v,t)} = \sqrt{\sigma^2_{L(u,v,t)}}$$

Measures of covariance between concentration and load of different pollutants from one source, $\sigma_{X(u_1,u_2,v,t)}$, $\sigma_{L(u_1,u_2,v,t)}$, as well as the coefficients of correlation between pollutants $\rho_{X(u_1,u_2,v,t)}$, $\rho_{L(u_1,u_2,v,t)}$ were also calculated in accordance with the following algorithms:*

(11) $$\sigma_{X(u_1,u_2,v,t)} =$$

$$[1/(n-1)] \sum_{i=1}^{n} [X(u_1,v,t)_i - \bar{X}(u_1,v,t)] \; [X(u_2,v,t)_i - \bar{X}(u_2,v,t)]$$

(12) $$\sigma_{L(u_1,u_2,v,t)} =$$

$$[1/(n-1)] \sum_{i=1}^{n} [L(u_1,v,t)_i - \bar{L}(u_1,v,t)] \; [L(u_2,v,t)_i - \bar{L}(u_2,v,t)]$$

(13) $$\rho_{X(u_1,u_2,v,t)} = \frac{\sigma_{X(u_1,u_2,v,t)}}{\sigma_{X(u_1,v,t)} \; \sigma_{X(u_2,v,t)}}$$

(14) $$\rho_{L(u_1,u_2,v,t)} = \frac{\sigma_{L(u_1,u_2,v,t)}}{\sigma_{L(u_1,v,t)} \; \sigma_{L(u_2,v,t)}}$$

---

* Only time periods containing measures of concentration of both pollutants of interest were used in calculating estimates of covariance.

Synthesizing NSS Time-Load Profiles

From this point forward capital letters are used to indicate functions pertaining to SM's and small letters those same quantities for NSS's. Thus, whereas $\overline{L}(u,v_1,t)$ represents the load of pollutant u emanating from standard mine (SM) v_1 during time period t, $\overline{l}(u,v_2,t)$ represents the load of pollutant u emanating from NSS v_2 during that same period of time.

It will be recalled that the first step in the process of synthesizing NSS time-load profiles was to select the SM time-load vector for the pollutant concerned that best fit the NSS data. To proceed with the fitting process, define the ratio $\Omega(v,t_1,t_2)$ as: *

$$(15) \qquad \Omega(v,t_1,t_2) = \frac{\overline{L}(v,t_2)}{\overline{L}(v,t_1)} \qquad \text{Where } t_1 < t_2$$

It follows from (15) that for any SM:

$$(16) \qquad \overline{L}(v,t_2=i) = [\overline{L}(v,t_1=i-j)]\,[\Omega(v,t_1=i-j,t_2=i)]$$

---

* Since the load measures for only one polluting element are addressed in the development formulae, the variable u is omitted from all of the expressions in this section for brevity and clarity. The procedures illustrated are repeated for each pollutant.

By our convention, small omega, ω, serves the same function for NSS's as large omega, Ω, does for SM's.

Although equation (16) may appear confusing at first glance, careful inspection will reveal that what is said, in essence, is that: where equation (15) defines the quantity Ω as the ratio of two average loads representing different cyclical months, the cyclical month of the load in the numerator of the ratio being later in the year than the cyclical month of the load in the denominator, equation (16) then states that the numerator load must be equal to the value of the ratio times the denominator load.

The reader is also asked to note that the ratio $\Omega(v,t_1,t_2)$ is an element of the time-load vector as defined on page 11 for source v. It is then apparent from (15) that the time-load vectors for SM's and NSS's may be expressed respectively in notational form as:

(17) $$\Gamma(v) = \Omega(v,t_1 = 1,\ t_2 = 2),\ \Omega(v,t_1 = 1,\ t_2 = 3),\ \text{----},\ \Omega(v,t_1 = 1,\ t_2 = m),\ \Omega(v,t_1 = 2,\ t_2 = 3),\ \text{----},\ \Omega(v,t_1 = m-1,\ t_2 = m)$$

and, similarly for NSS,

(18) $$\gamma(v) = \omega(v,t_1 = 1,\ t_2 = 2),\ \omega(v,t_1 = 1,\ t_2 = 3),\ \text{----},\ \omega(v,t_1 = m-1,\ t_2 = m)$$

Where: m = the number of time periods per cycle (since the time period of consideration is a month, and the cycle length of consideration is a year, m equals 12 for our purposes).

Now, to find the SM, v^*, whose time-load vector best fits the data available for a particular NSS, say NSS, v', the squared difference function $\Delta(v,v')$ is defined as:

$$(19) \qquad \Delta(v,v') = \sum_{i=a}^{n} \sum_{j=a}^{n} [\Omega(v,t_1 = i,\ t_2 = j) - \omega(v',t_1 = i,\ t_2 = j)]^2$$

Where: the running indices i and j pass only over those times for which a load point is available for NSS v'.

Then, the SM, v*, that best fits the data for NSS v', is that SM that minimizes equation (19). In notational form this may be expressed as:

$$(20) \qquad \min_{v} \ \Delta(v,v') = \Delta(v^*,v')$$

In the cases where only one time-load data point is available for NSS, v', the SM that produces the least difference: $\overline{L}(v,t) - \overline{l}(v',t)$ is chosen as being the SM best fitting the time-load vector of NSS, v'.

Now that a best fit time-load vector has been selected for NSS, v', it remains to adjust the magnitude of this vector so that it passes through the available NSS monthly load data with a minimum squared error. This was accomplished by defining a squared difference function, λ such that:

$$(21) \qquad \lambda = \sum_{i=2}^{12} [\bar{\bar{I}}(v', t=i) - \bar{z}(v', t=1) \ \Omega(v^*, t_1 = 1, t_2 = i)]^2$$

Where: $\bar{z}(v', t=i)$ equals a synthesized mean load for NSS v' in the i^{th} cyclical month.

Where: The running index i covers only those months for which time-load data are available for NSS,v'.

It follows that a value of $\bar{z}(v', t=1)$ that minimizes λ is sufficient to determine the time-load profile that best fits data available for NSS, v'. Call this value $\bar{z}^*(v', t=1)$.

Now, $\bar{z}^*(v', t=1)$ will be found. This is accomplished by setting the first derivative of λ with respect to $\bar{z}$ equal to zero and solving for $\bar{z}$.

$$\frac{d\lambda}{dz} = 0 =$$

$$\sum_{i=2}^{12} -2 [\bar{\bar{I}}(v', t=i) - \bar{z}(v', t=1) \ \Omega(v^*, t_1=1, t_2=i)] \ \Omega(v^*, t_1=1, t_2=i)$$

and it follows,

$$(22) \qquad \bar{z}^*(v',t=1) = \frac{\sum_{i=2}^{12} \bar{I}(v',t=i)\ \Omega(v^*,t_1=1,t_2=i)}{\sum_{i-2}^{12} \Omega^2(v^*,t_1=1,t_2=i)}$$

The best fit time-load profile for NSS, v' follows directly from (22) and is:

$$(23) \qquad \Phi(v^*,v') = \bar{z}^*(v',t=1),\ \bar{z}^*(v',t=1)\ \Omega(v^*,t_1=1,\ t_2=2),$$
$$\text{----},\ \bar{z}^*(v',t=1)\ \Omega(v^*,t_1=1,t_2=11),$$
$$\bar{z}^*(v',t=1)\ \Omega(v^*,t_1=1,\ t_2=12)$$

The procedure described above is illustrated by an example of its application in the following section.

AN ILLUSTRATIVE EXAMPLE OF THE NSS FITTING TECHNIQUE

Each NSS, with non-zero flow, is fitted to the time-load vector of one of the standard mines. The fitting procedure is done for each pollutant of the NSS where data exist.

There are two steps in the procedure; first, finding which SM time-load vector most closely approximates the time-load vector of the NSS in question, and secondly, adjusting the magnitude of the selected time-load vector to the NSS data (moving the curve up and down).

The NSS chosen for this example is 080111, located in Maryland, sub-basin 29 (Leading Creek). Load data exist for two months, September and November. This particular NSS was chosen because it had only two monthly load data points. This is sufficient to illustrate the technique but avoids overly long and complex arithematical expressions.

	Characteristic	September	November
080111	Flow (cfs)	0.0446	0.0022
	Acidity (mg/l)	24	36
	Hardness (mg/l)	45	27
	Iron (mg/l)	0.2	11.2
	Sulfate (mg/l)	41	32
	Al (mg/l)	0.2	0.2

This example demonstrates the procedure for fitting acidity. Other pollutants are handled similarly. The acidity load for September for NSS 080111 is:

$$(0.19 \frac{\text{lb.sec.}}{\text{mg.day}}) \quad x \quad (24 \text{ mg/l}) \quad x$$

$$(28.32 \text{ l/ft}^3) \quad x \quad 0.0446 \text{ ft}^3/\text{sec} \quad = \quad 5.76 \text{ lbs/day}$$

Similarly, the acidity load in November is 0.426 lbs/day.

The fitting process compares ratios of loads between the NSS and each SM in turn. This means the time-load vector of each SM is compared to that of the NSS.

The ratio of two month's loads for an SM is, from expression (15):

$$\Omega(v,t_1,t_2) = \bar{L}(v,t_2) \; / \; \bar{L}(v,t_1) \; : \; t_1 < t_2$$

The two months involved are represented by t_1 and t_2; and the mine designation is v.

The acidity load ratio for NSS 080111, is ω =

$$0.426/5.76 = 0.074$$

The corresponding ratios for each SM are shown in Table 1.

To find the SM whose time-load vector best fits that of the NSS, we find the minimum squared difference of ratios according to expression (19). The results of expression (19) for acidity load and the two months involved are shown in Table 2.

TABLE 1

STANDARD MINE ACIDITY TIME-LOAD RATIOS

SM #	SM NAME	SM NOVEMBER/SEPTEMBER ACIDITY TIME-LOAD RATIO
1	BC-01	1.052
2	Florence - 1	0.921
3	Florence - 2	1.008
4	GT01-03	0.643
5	GT06-01	1.636
6	Oneida	0.755
7	Piper	0.776
8	RT06-05	1.351
9	RT06-09	1.513
10	RT06-12	1.962
11	RT06-23	1.586
12	RT09-11	1.201
13	RT88-03	1.544
14	Sagamore	1.048

TABLE 2

SQUARED TIME-LOAD RATIO DIFFERENCES

SM #	NSS #	SQUARED TIME-LOAD RATIO DIFFERENCE	
1	080111	$(1,v') = (1.052-0.074)^2 =$	0.956
2	080111	$(2,v') = (0.921-0.074)^2 =$	0.717
3	080111	$(3,v') = (1.008-0.074)^2 =$	0.872
4	080111	$(4,v') = (0.643-0.074)^2 =$	0.324
5	080111	$(5,v') = (1.636-0.074)^2 =$	2.440
6	080111	$(6,v') = (0.755-0.074)^2 =$	0.464
7	080111	$(7,v') = (0.776-0.074)^2 =$	0.493
8	080111	$(8,v') = (1.351-0.074)^2 =$	1.631
9	080111	$(9,v') = (1.513-0.074)^2 =$	2.071
10	080111	$(10,v') = (1.962-0.074)^2 =$	3.565
11	080111	$(11,v') = (1.586-0.074)^2 =$	2.286
12	080111	$(12,v') = (1.201-0.074)^2 =$	1.270
13	080111	$(13,v') = (1.544-0.074)^2 =$	2.161
14	080111	$(14,v') = (1.048-0.074)^2 =$	0.949

Inspection of Table 2 reveals that expression (19) is minimized when the time-load pattern of SM GT01-03 is chosen as having the time-load vector representing NSS 080111.

The final step in the fitting process is to adjust the time-load vector of GT01-03 to pass through the NSS data points with minimum squared error.

Expression (22) defines the fitted NSS load, $\overline{z}^*(v',t=1)$, for the month of January that minimizes expression (21). For the example at hand, expression (22) reduces to:

(24)
$$\overline{z}^*(v^*,t=1) = \frac{\overline{T}(v',t=9)\ \Omega(v^*,t_1=1,t_2=9) + \overline{T}(v',t=11)\ \Omega(v^*,t_1=1,t_2=11)}{\Omega^2(v^*,t_1=1,t_2=9) + \Omega^2(v^*,t_1=1,t_2=11)}$$

Where: v' = NSS 080111

v^* = SM GT01-03

Now, the values of the components in expression (24) are:

$\overline{T}(v',t=9) = 5.76$

$\overline{T}(v',t=11) = 0.426$

$\Omega(v^*,t_1=1,t_2=9) = 0.340$

$\Omega(v^*,t_1=1,t_2=11) = 0.219$

Inserting these values into expression (24) produces a best fit

January acidic load for NSS 080111 of:

$$\overline{z}^{*}(v', t=1) = 12.54 \text{ lbs/day}$$

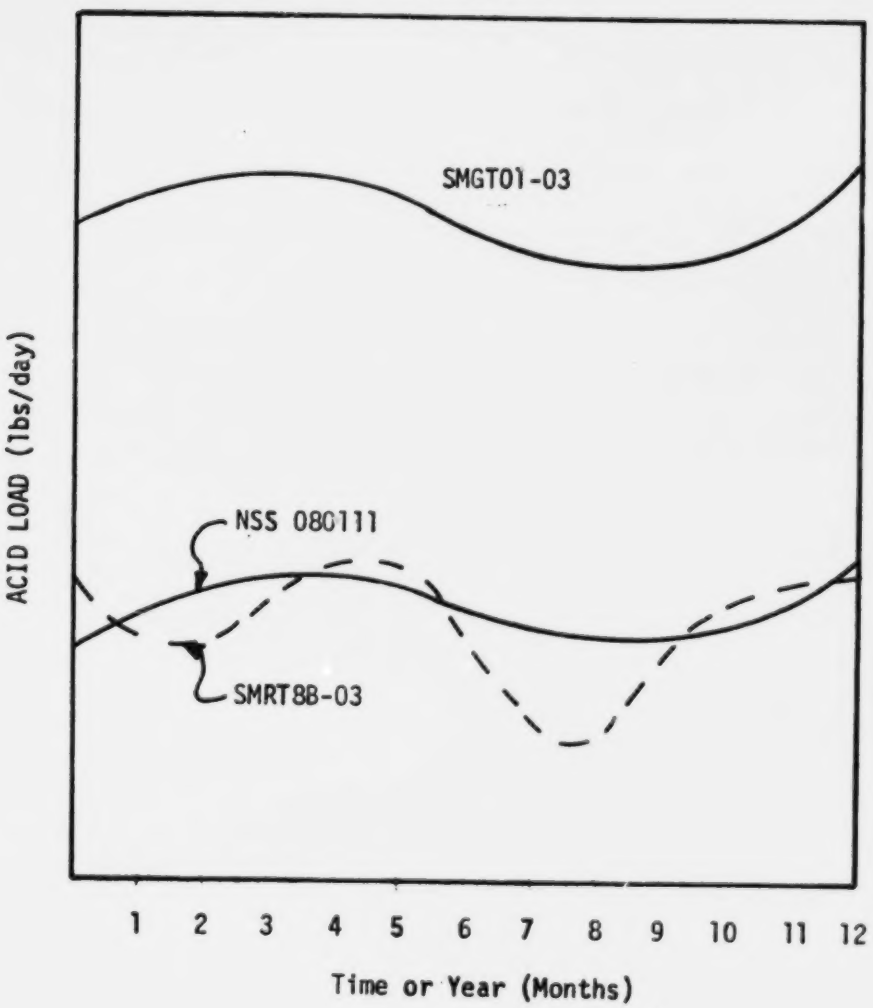
In this manner the time-load profile for NSS 080111 has the shape of GT01-03, although the magnitude of its load points are much less than GT01-03's load points.

It is interesting to note that there are standard mines other than GT01-03 that have acidity loads closer in magnitude to NSS 080111. However, none of these SM were chosen as the best fit because their "shapes" were not as similar to the shape of NSS 080111 as was the shape of GT01-03. This point is illustrated in Figure 1-A.

FIGURE 1-A

TYPICAL STANDARD MINE LOAD PATTERNS

(Schematic)



CHAPTER IV

RESULTS OF ACID MINE DRAINAGE CONTAMINATION ANALYSIS

Introduction

Chapter III of this volume describes the methodology used in analyzing the acid mine drainage data. The results of these analyses are described and discussed in this chapter.

The complete results of some phases of the analysis are voluminous and tedious in their detail. Therefore, for the most part, only summaries and examples of the results are included in this chapter. The complete results themselves are forwarded as succeeding volumes of this report so as to be available to the reader interested in the results in detail. These are:

Volume II - Standard Mine (SM) Analysis - Acid Mine Drainage statistics for each standard mine

Volume III - (in four sections) - Synthesized NSS Time-Load Profiles - presents the results of the Non-Standard Source time-load profile synthesizing process.

Volume IV - Source Ranking by Acidity Load - contains the ranking of all mine sources segregated by subbasin and cyclical month.

The detailed descriptions of the contents of Volumes II, III and IV are presented in Appendix IV to this volume.

Results of the Analysis of Standard Mine Data

Fourteen mine openings were chosen as Standard Mines (SM). These 14 mine openings are identified as:

Piper	GT06-01
Sagamore	RT06-05
Oneida	RT06-09
Florence I	RT06-12
Florence II	RT06-23
BC-01	RT09-11
GT01-03	RT8B-03

A more comprehensive identification of the SM's, along with their locations, is contained in Appendix I to this volume.

Even though availability of data was one of the criteria for choice as an SM, data pertaining to some of the pollutants were not available, even for the SM's. In particular, there was an almost total absence of data pertaining to Alkalinity and Manganese. This trend was duplicated in the case of the Non-Standard Sources (NSS). The fact that essentially no SM Alkalinity and Manganese data were available for SM's invalidated any application of the fitting techniques of Chapter III in the cases of these two pollutants. However, this did not affect the completeness of the results since data on these same pollutants were also absent from the NSS data bank.* Availability of data by pollutant and cyclical month is shown for each of the 14 SM's in Table 3. The reader interested in a complete recounting of the data used in the analysis of standard mines is referred to Volume II of this report which is under a separate cover.

* Out of 2,298 active NSS, only 752 had Alkalinity data and none had Manganese data.

TABLE 3

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
BC-01	JAN	X	X	X	X	X	X		X	
	FEB	X	X	X	X	X	X		X	
	MAR	X	X	X	X	X			X	
	APR	X	X	X	X	X	X		X	
	MAY	X	X	X	X	X	X		X	
	JUNE	X	X	X	X	X	X		X	
	JULY	X	X	X	X	X	X		X	
	AUG	X	X	X	X	X	X		X	
	SEPT	X	X	X	X	X	X		X	
	OCT	X	X	X	X	X	X		X	
	NOV	X	X	X	X	X	X		X	
	DEC	X	X	X	X	X	X		X	
FLOR- I	JAN	X	X						X	
	FEB	X	X						X	
	MAR	X	X						X	
	APR	X	X						X	
	MAY	X	X						X	
	JUNE	X	X						X	
	JULY	X	X						X	
	AUG	X	X						X	
	SEPT	X	X						X	
	OCT	X	X						X	
	NOV	X	X						X	
	DEC	X	X						X	

TABLE 3 (Continued)

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
FLOR II	JAN	X	X	X	X	X				
	FEB	X	X	X	X	X				
	MAR	X	X	X	X	X				
	APR	X	X	X		X				
	MAY	X	X	X	X	X				
	JUNE	X	X	X		X				
	JULY	X	X	X		X				
	AUG	X	X	X		X			X	
	SEPT	X	X	X	X	X				
	OCT	X	X	X	X	X				
	NOV	X	X	X	X	X				
	DEC	X	X	X		X				
GT01-02	JAN	X	X	X	X	X				X
	FEB	X	X	X	X	X				X
	MAR	X	X	X	X	X				X
	APR	X	X	X	X	X				X
	MAY	X	X	X	X	X				X
	JUNE	X	X	X	X	X				X
	JULY	X	X	X	X	X				X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X				X
	OCT	X	X	X	X	X				X
	NOV	X	X	X	X	X	X			X
	DEC	X	X	X	X	X	X			X

TABLE 3 (Continued)

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
ONEIDA	JAN	X	X					X	X	
	FEB	X	X						X	
	MAR	X	X						X	
	APR	X	X						X	
	MAY	X	X						X	
	JUNE	X	X						X	
	JULY	X	X						X	
	AUG	X	X						X	
	SEPT	X	X						X	
	OCT	X	X						X	
	NOV	X	X						X	
	DEC	X	X						X	
GT06-01	JAN	X	X	X	X	X	X		X	X
	FEB	X	X	X	X	X			X	X
	MAR	X	X	X	X	X			X	X
	APR	X	X	X	X	X			X	X
	MAY	X	X	X	X	X			X	X
	JUNE	X	X	X	X	X	X		X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X				X
	SEPT	X	X	X	X	X	X		X	X
	OCT	X	X	X	X	X		X	X	X
	NOV	X	X	X	X	X	X	X	X	X
	DEC	X	X	X	X	X	X	X		X

TABLE 3 (Continued)

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
RT06-09	JAN	X	X	X	X	X				X
	FEB	X	X	X	X	X			X	X
	MAR	X	X	X	X	X			X	X
	APR	X	X	X	X	X			X	X
	MAY	X	X	X	X	X			X	X
	JUNE	X	X	X	X	X			X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X			X	X
	OCT	X	X	X	X	X			X	X
	NOV	X	X	X	X	X	X		X	X
	DEC	X	X	X	X	X	X		X	X
RT06-12	JAN	X	X	X	X	X				X
	FEB	X	X	X	X	X			X	X
	MAR	X	X	X	X	X			X	X
	APR	X	X	X	X	X			X	X
	MAY	X	X	X	X	X				X
	JUNE	X	X	X	X	X			X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X			X	X
	OCT	X	X	X	X	X			X	X
	NOV	X	X	X	X	X	X		X	X
	DEC	X	X	X	X	X	X		X	X

TABLE 3 (Continued)

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
RT06-23	JAN	X	X	X	X	X			X	X
	FEB	X	X	X	X	X				X
	MAR	X	X	X	X	X			X	X
	APR	X	X	X	X	X			X	X
	MAY	X	X	X	X	X				X
	JUNE	X	X	X	X	X			X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X			X	X
	OCT	X	X	X	X	X			X	X
	NOV	X	X	X	X	X	X		X	X
	DEC	X	X	X	X	X	X			X
RT09-11	JAN	X	X	X	X	X				X
	FEB	X	X	X	X	X				X
	MAR	X	X	X	X	X			X	X
	APR	X	X	X	X	X				X
	MAY	X	X	X	X	X			X	X
	JUNE	X	X	X	X	X			X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X			X	X
	OCT	X	X	X	X	X	X		X	X
	NOV	X	X	X	X	X	X		X	X
	DEC	X	X	X	X	X			X	X

TABLE 3 (Continued)

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
RT8B-03	JAN	X	X	X	X	X				X
	FEB	X	X	X	X	X				X
	MAR	X	X	X	X	X				X
	APR	X	X	X	X	X				X
	MAY	X	X	X	X	X			X	X
	JUNE	X	X	X	X	X			X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X			X	X
	OCT	X	X	X	X	X			X	X
	NOV	X	X	X	X	X	X		X	X
	DEC	X	X	X	X	X	X			X
SAGA-MORE	JAN	X	X						X	
	FEB	X	X						X	
	MAR	X	X						X	
	APR	X	X						X	
	MAY	X	X						X	
	JUNE	X	X						X	
	JULY	X	X						X	
	AUG	X	X						X	
	SEPT	X	X						X	
	OCT	X	X						X	
	NOV	X	X						X	
	DEC	X	X						X	

TABLE 3 (Continued)

AVAILABILITY OF ACID MINE DRAINAGE POLLUTION DATA

FOR STANDARD MINES BY CYCLICAL MONTH

Standard Mine	Month	pH	Acidity	Total Iron	Sulfate	Hardness	Manganese	Alkalinity	Iron	Aluminum
PIPER	JAN	X	X							
	FEB	X	X						X	
	MAR	X	X						X	
	APR	X	X		X					
	MAY	X	X							
	JUNE	X	X		X				X	
	JULY	X	X		X				X	
	AUG	X	X		X				X	
	SEPT	X	X						X	
	OCT	X	X		X				X	
	NOV	X	X						X	
	DEC	X	X						X	
RT06-05	JAN	X	X	X	X	X	X		X	X
	FEB	X	X	X	X	X		X	X	X
	MAR	X	X	X	X	X		X	X	X
	APR	X	X	X	X	X			X	X
	MAY	X	X	X	X	X			X	X
	JUNE	X	X	X	X	X	X		X	X
	JULY	X	X	X	X	X			X	X
	AUG	X	X	X	X	X			X	X
	SEPT	X	X	X	X	X	X		X	X
	OCT	X	X	X	X	X	X		X	X
	NOV	X	X	X	X	X	X		X	X
	DEC	X	X	X	X	X			X	X

As presented in Chapter III, statistical estimates of the following descriptive parameters were calculated for each pollutant by cyclical month and SM:

- Mean Concentration.
- Mean Load.
- Variance and standard deviation of concentration.
- Variance and standard deviation of load.
- Covariance of concentration between pollutants.
- Covariance of load between pollutants.
- Coefficient of correlation between concentration of pollutants.
- Coefficient of correlation between pollutant loads.

A typical printout of the results for one SM and cyclical month, (BC-01 and January), is shown in Table 4. A complete set of these printouts for each SM and cyclical month is contained in Volume II of this report. With regard to Table 4, the reader should keep in mind that the units of concentration are milligrams per liter, the units of flow are liters per second,* and that load is in pounds per day. Also, mean load is not necessarily equivalent to the product of mean concentration and mean flow since mean load is the mean of a product and not the product of means.

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* In volume II only

TABLE 4

STATISTICS FOR STANDARD MINES

Standard Mine BC-01 January

	MEAN	VARIANCE	STD. DEV.	MEAN LOAD **	VAR. LOAD	STD.DEV. LOAD
PH	3.74411E+00	6.21319E-03	7.88238E-02			
ACIDITY	4.28785E+02	7.53988E+02	2.74588E+01	6.00874E+03	1.99768E+06	1.41339E+03
TOTAL IRON	1.59117E+02	1.13576E+03	3.37011E+01	2.22977E+03	1.53564E+05	3.91872E+02
SULFATE	1.32517E+03	1.22885E+04	1.10853E+02	1.85702E+04	5.71429E+06	2.39045E+03
HARDNESS	9.64500E+02	1.72942E+04	1.31507E+02	1.35159E+04	8.95701E+06	2.99282E+03
MN	1.71833E+01	1.05296E+01	3.24494E+00	2.40796E+02	3.81043E+03	6.17287E+01
ALKALINITY	0.0000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
IRON	1.63235E+02	6.77939E+02	2.60372E+01	2.28748E+03	4.83316E+04	2.19844E+02
CHLORIDE	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
ALUMINUM	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
FLOW *	7.37547E+01	1.73840E+02	1.31848E+01			

* Liters per second

** Pounds per day

TABLE 4 (Continued)

STATISTICS FOR STANDARD MINES*

COVARIANCE AND CORRELATION COEFFICIENT OF LOAD

STANDARD MINE BC-01 JANUARY

	ACIDITY	TOTAL IRON	SULFATE	HARDNESS	MN	IRON
ACIDITY						
Covariance		3.027E+05	3.037E+06	3.154E+06	4.775E+04	2.250E+05
Corr. Coef.		5.465E-01	8.989E-01	7.457E-01	5.473E-01	7.242E-01
TOTAL IRON						
Covariance			5.043E+05	4.105E+05	6.276E+03	4.211E+04
Corr. Coef.			5.384E-01	3.500E-01	2.594E-01	4.888E-01
SULFATE						
Covariance				3.942E+06	6.697E+04	3.757E+05
Corr. Coef.				5.511E-01	4.538E-01	7.150E-01
HARDNESS						
Covariance					1.798E+05	2.498E+05
Corr. Coef.					9.733E-01	3.796E-01
MN						
Covariance						3.434E+03
Corr. Coef.						2.530E-01

* No values for Alkalinity, Chloride or Aluminum.

TABLE 4 (Continued)

STATISTICS FOR STANDARD MINES*

COVARIANCE AND CORRELATION COEFFICIENT OF CONCENTRATION

STANDARD MINE BC-01 JANUARY

	ACIDITY	TOTAL IRON	SULFATE	HARDNESS	MN	IRON
PH						
Covariance	7.225E-02	-1.727E-01	2.276E-01	3.664E+00	1.008E-01	1.452E-01
Corr. Coef.	3.338E-02	-6.501E-02	2.604E-02	3.535E-01	3.942E-01	7.075E-02
ACIDITY						
Covariance		-1.959E+02	-1.533E+03	-2.936E+03	-7.486E+01	-2.391E+02
Corr. Coef.		-2.116E-01	-5.038E-01	-8.131E-01	-8.401E-01	-3.344E-01
TOTAL IRON						
Covariance			1.672E+03	-2.345E+02	-4.883E+00	4.677E+02
Corr. Coef.			4.477E-01	-5.291E-02	-4.465E-02	5.330E-01
SULFATE						
Covariance				-5.200E+02	5.310E+00	2.206E+03
Corr. Coef.				-3.567E-02	1.476E-02	7.644E-01
HARDNESS						
Covariance					4.213E+02	-2.345E+02
Corr. Coef.					9.873E-01	-6.848E-02
MN						
Covariance						-4.883E+00
Corr. Coef.						-5.780E-02

* No values for Alkalinity, Chloride or Aluminum.

Inspection of the totality of calculations in Volume II reveals that concentration is far more stable and less subject to month-to-month variation than is flow. Average monthly flow and concentration of acidity for BC-01 has been plotted for a full cyclical year in Figure 2.* Inspection of Figure 2 indicates the significantly greater month-to-month variation of flow over that of acid concentration. These differences may be succinctly highlighted by comparing coefficients of variation for the two quantities.**

Figure 3 is a plot of the within the month coefficients of variation for flow and concentration of acidity for SM BC-01. Bearing in mind that low coefficients of variation indicate relative stability while high coefficients of variation indicate relative instability, it will be seen from Figure 3 that concentration of acidity is generally more stable than flow. This trend is even more pronounced if one considers the long term, between months coefficients of variation. Here, the coefficient of variation for concentration of acidity at BC-01 is 0.02 over the cyclical year while that for flow is 0.39, a factor of more than 10 greater. Inspection of Volume II reveals that the relative stability patterns exhibited by BC-01 for flow and concentration of acidity are generally consistent over all SM's and pollutants. That is, flow is much more variable than concentration, particularly if taken over the longer term.

---

* Figure 2 is presented on three-cycle semi-log paper, as are many of the graphs in this chapter, in order to encompass the full range of values on one page.

** The coefficient of variation is the standard deviation divided by the mean. Thus, a quantity experiencing a great deal of variation when compared to its mean will have a large coefficient of variation while a very stable quantity will have a low coefficient of variation. The coefficient of variation was not computed as a standard statistic for all sources, but is used here for illustrative purposes.

FIGURE 2

ACIDITY CONCENTRATION AND FLOW BY CYCLICAL MONTH

STANDARD MINE BC-01

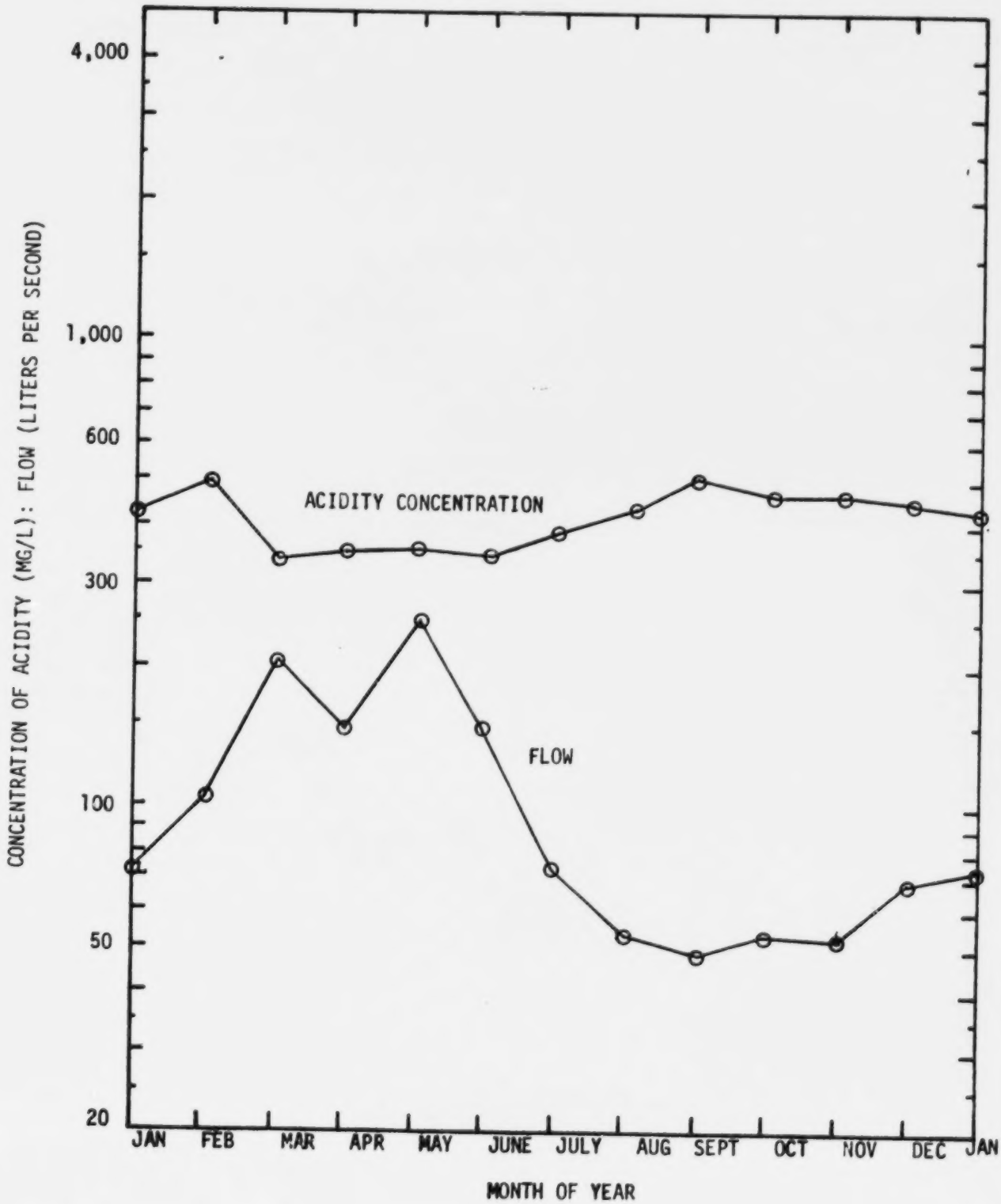
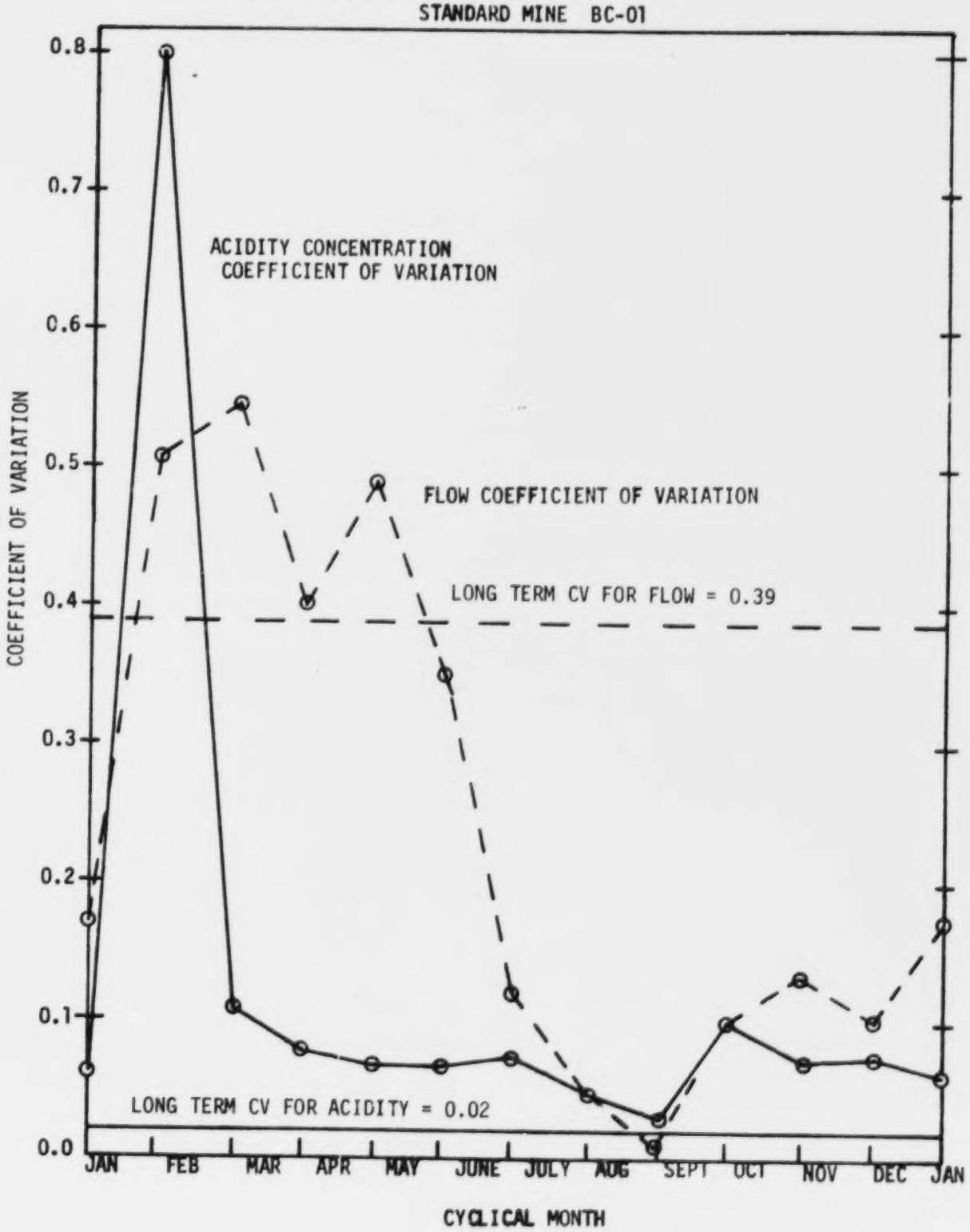


FIGURE 3

COMPARISON OF SHORT-TERM COEFFICIENTS OF VARIATION
FOR ACIDITY CONCENTRATION AND FLOW

STANDARD MINE BC-01



The fact that the long term coefficient of variation for concentration is consistently smaller than the short term coefficient of variation leads to the conclusion that errors in measurement and other short term "noise" are overwhelmed by long term stability in the case of concentration. Conversely, the fact that the long term coefficients of variation do not tend to diminish greatly from the short term coefficients, in the case of flow, suggests that there is, in fact, a good deal more true long and short term variation in the case of flow.

These observations are further supported by the fact that estimates of covariance between concentration of pollutants tends to be erratic and inconclusive. The signs (+ or -) of the within month covariance estimates between concentrations of different pollutants occasionally shift from month to month, and the coefficients of correlation tend to be weak.*

---

* Determination of what constitutes a weak coefficient of correlation is always a matter of interpretation and controversy. One interpretation is that 30 percent of the variation in one variable is explained by the variation of another variable when the coefficient of correlation is 0.3. However, it is entirely possible to obtain a correlation of 30 percent or even higher, by chance, where there is in fact, no cause and effect relationship between the two variables. For this reason, many scientists, particularly physical scientists, do not consider coefficients of correlation less than about 0.8. significant in the absence of knowledge of a cause and effect relationship and/or a large data base.

A positive covariance signifies a direct correlation between pollutants so that when the concentration of one goes up, the other tends to go up also. A negative covariance signifies the converse. In the absence of knowledge to the contrary, shifting covariance sign coupled with weak coefficients of correlation indicate that apparent correlation is likely to be caused by random variations rather than by an actual cause and effect relationship. In this case there is no apriori knowledge that would lead one to expect a shifting covariance sign.

Short term covariance between pollutant loads is dominated by flow. Thus, the stronger and more stable short term correlation between loads as compared to concentrations evidenced in Table 4 and in Volume II, reflects the fact that the same flow quantities are used to calculate load for all pollutants within a given cyclical month. It may be seen from inspection of the data in Table 4 that several of the coefficients of correlation between the concentrations of different pairs of pollutants are negative; whereas the coefficients of correlation between load for these same pairs of pollutants are positive. This illustrates how dominant flow is in determining load. The short term variation of flow is so much greater than that of concentration that an apparent negative correlation between concentrations is completely overwhelmed by flow variation in the computation of load.

The covariance and coefficients of correlation shown in Table 4 are typical of those for all months and SM's.*

Figures 4 through 17 are plots of the average monthly loads of the 14 SM's.** These plots clearly show the strong long term correlation that exists between loads of the various pollutants considered. The relative magnitudes of the load values of the pollutants show a rather remarkably consistent relationship even though there may be considerable variation in the absolute values of load between months. Also, the general pattern of the variation of loads evidences a good deal of similarity between SM's. Based on these observations, it is felt that the observed variation in the long term load patterns is primarily the result of month-to-month variation in flow rather than in concentration. If true, these observations have some rather far reaching consequences.

---

* The coefficients of correlation were calculated by dividing the estimate of covariance by the product of the estimates of standard deviation for the two variables involved. In a few cases the estimates of standard deviation and that of covariance encompass different numbers of sample points, resulting in a misleading estimate of the coefficients of correlation. This discrepancy comes about as the result of having non-simultaneous samples of concentration for the two pollutants involved, i.e., measurements were taken at different times during the week, by field crews.

** Values for manganese were either too low for plotting in the ranges given, or did not exist.

FIGURE 4

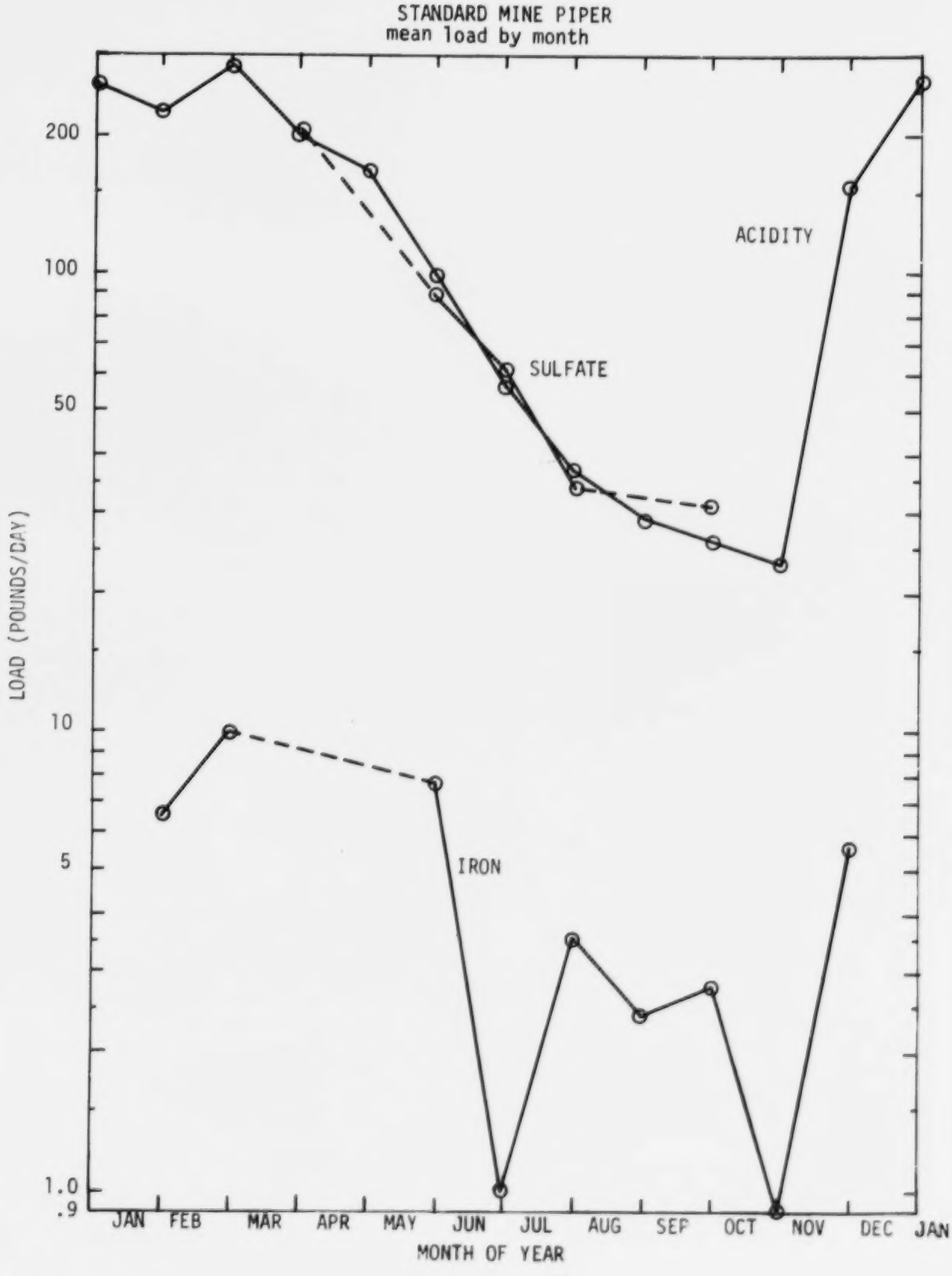

STANDARD MINE PIPER
mean load by month
200
100
50
10
5
1.0
.9
LOAD (POUNDS/DAY)
ACIDITY
SULFATE
IRON
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
MONTH OF YEAR

FIGURE 5

STANDARD MINE SAGAMORE
mean load by month

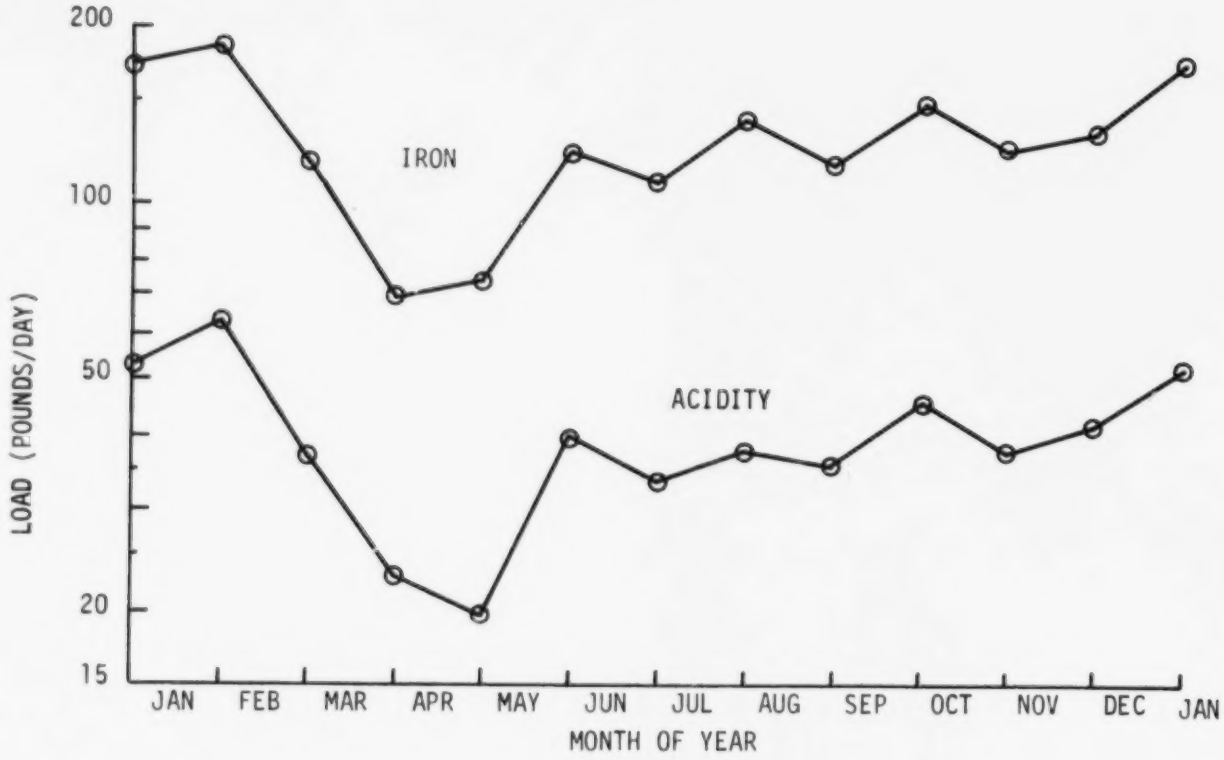


FIGURE 6

STANDARD MINE ONEIDA
mean load by month

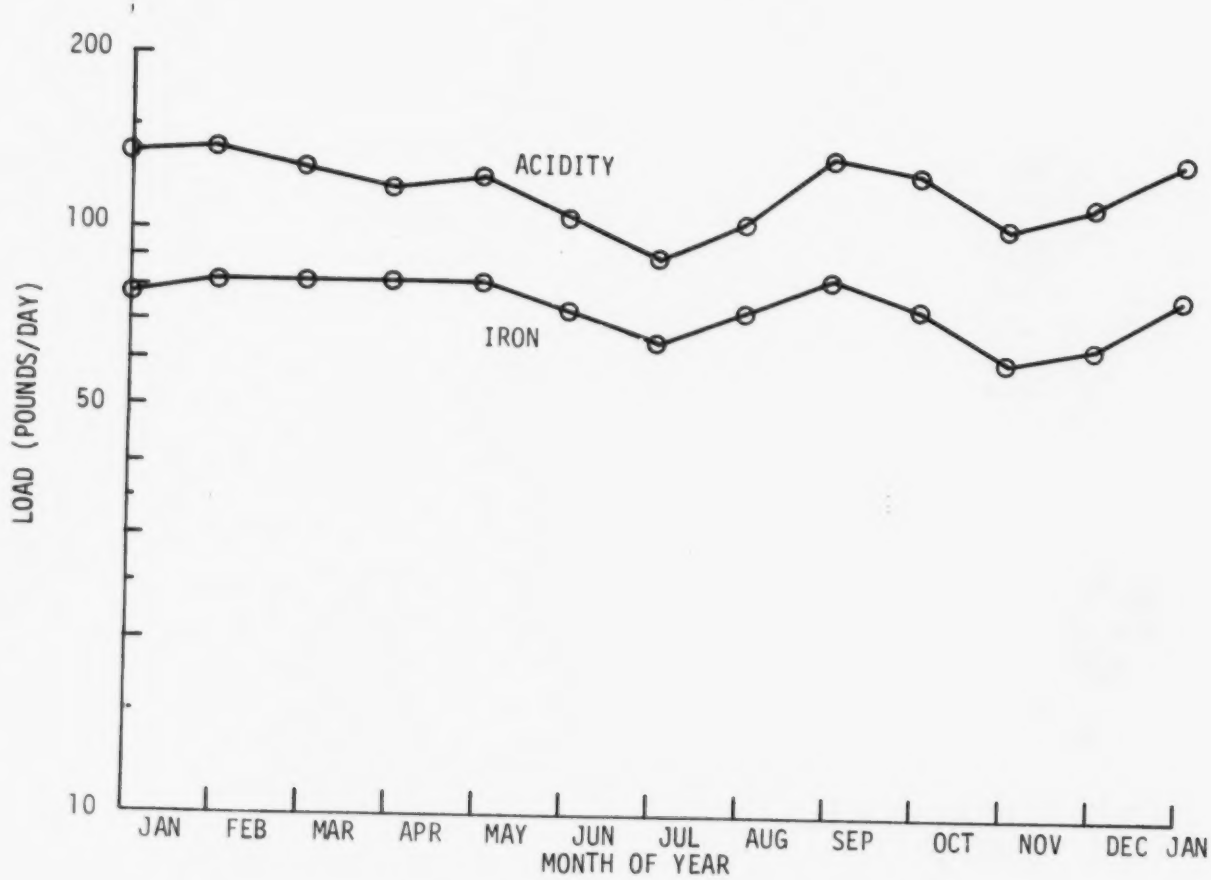


FIGURE 7

STANDARD MINE FLORENCE I
mean load by month

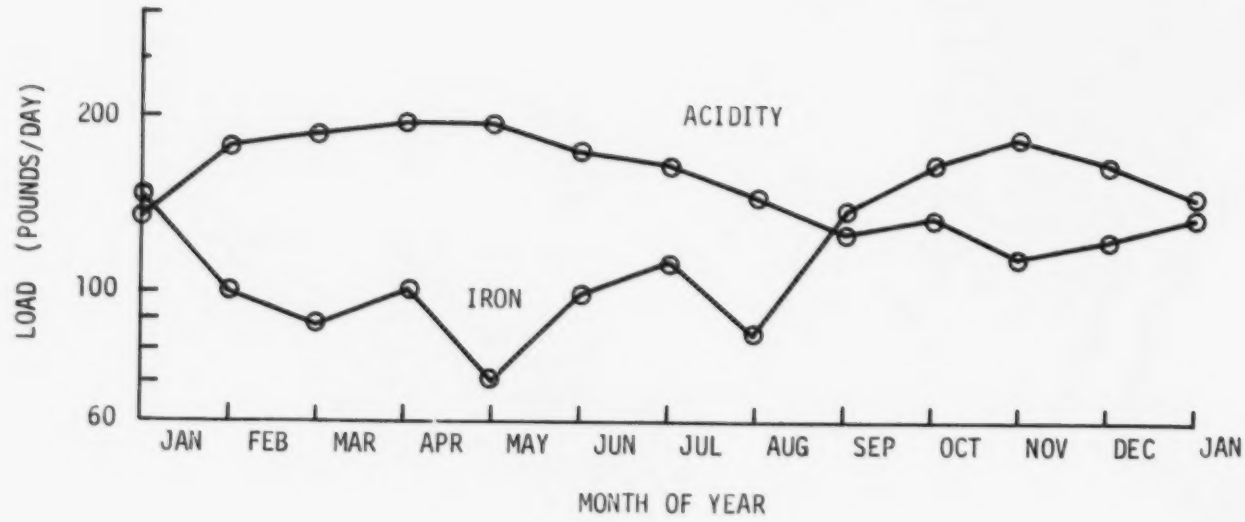


FIGURE 8

STANDARD MINE FLORENCE II
Mean load by month

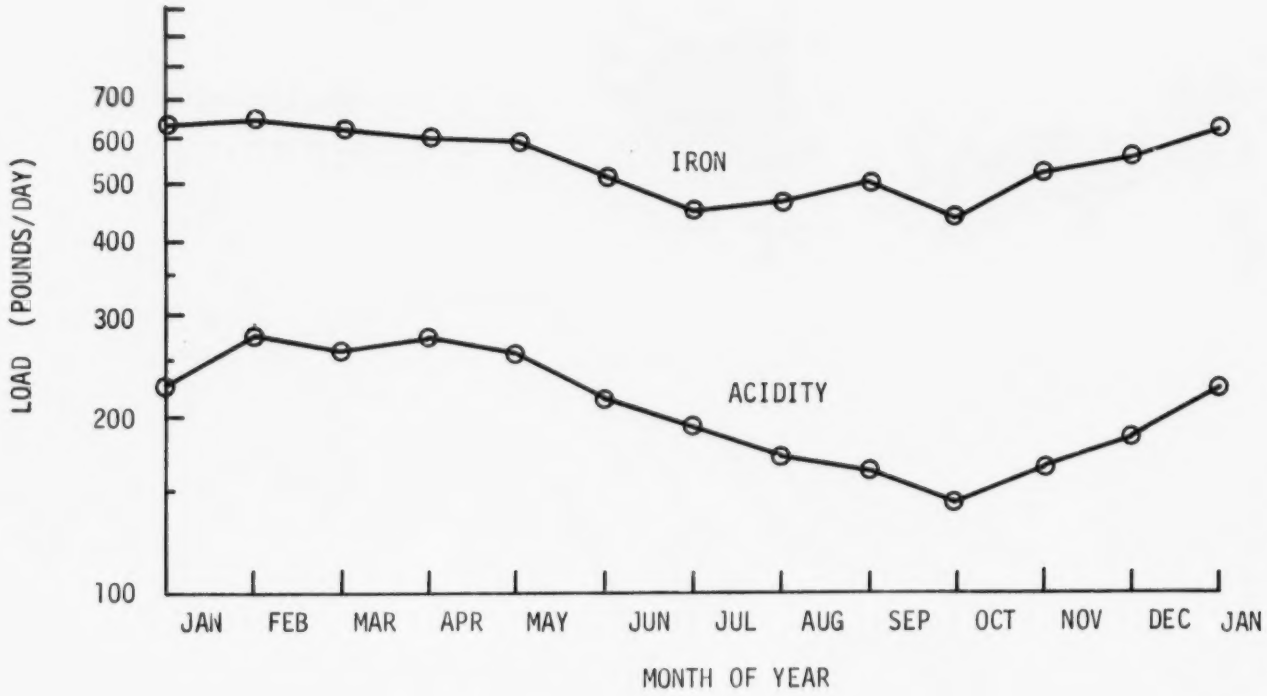


FIGURE 9

STANDARD MINE BC-01
mean load by month

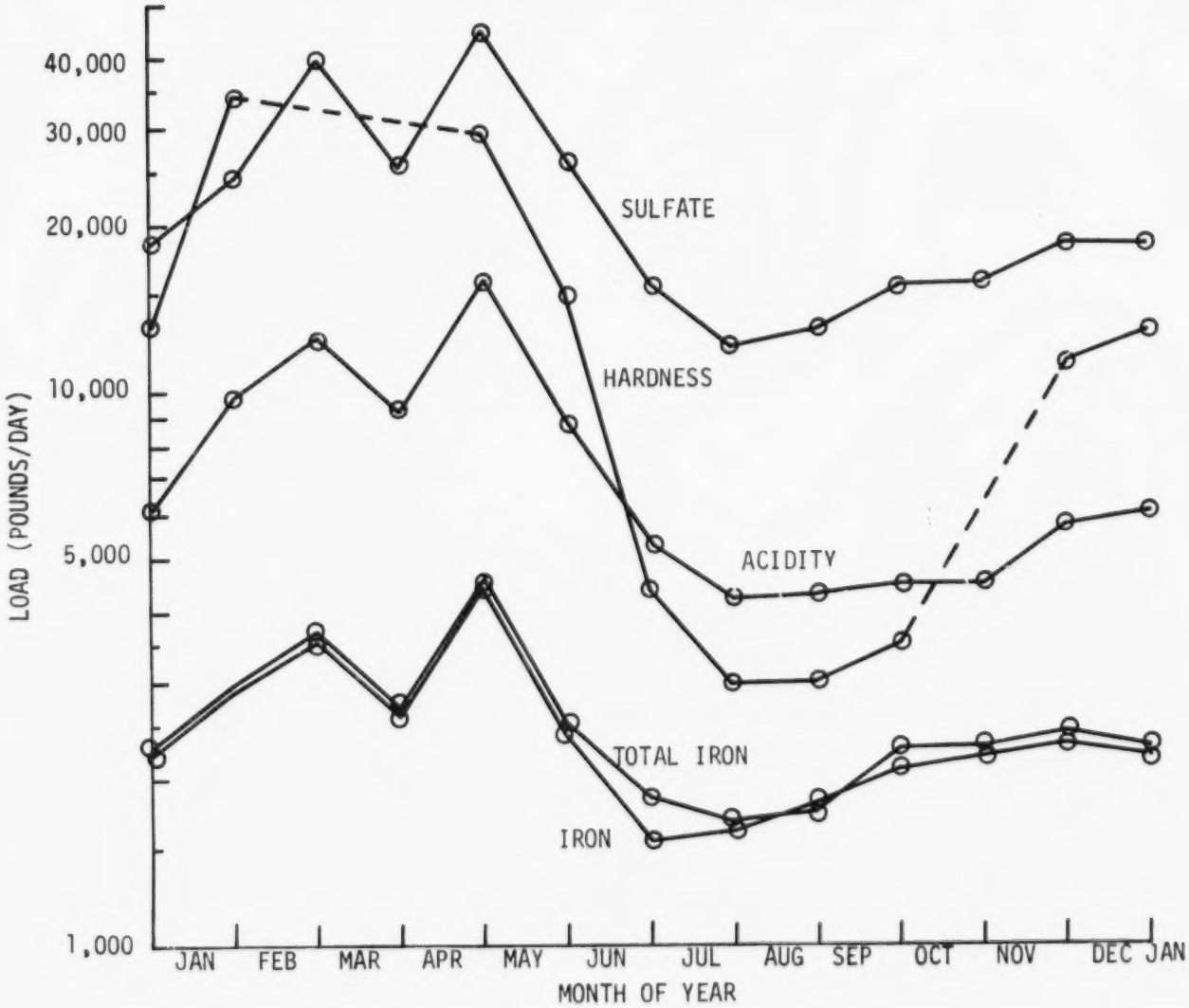


FIGURE 10

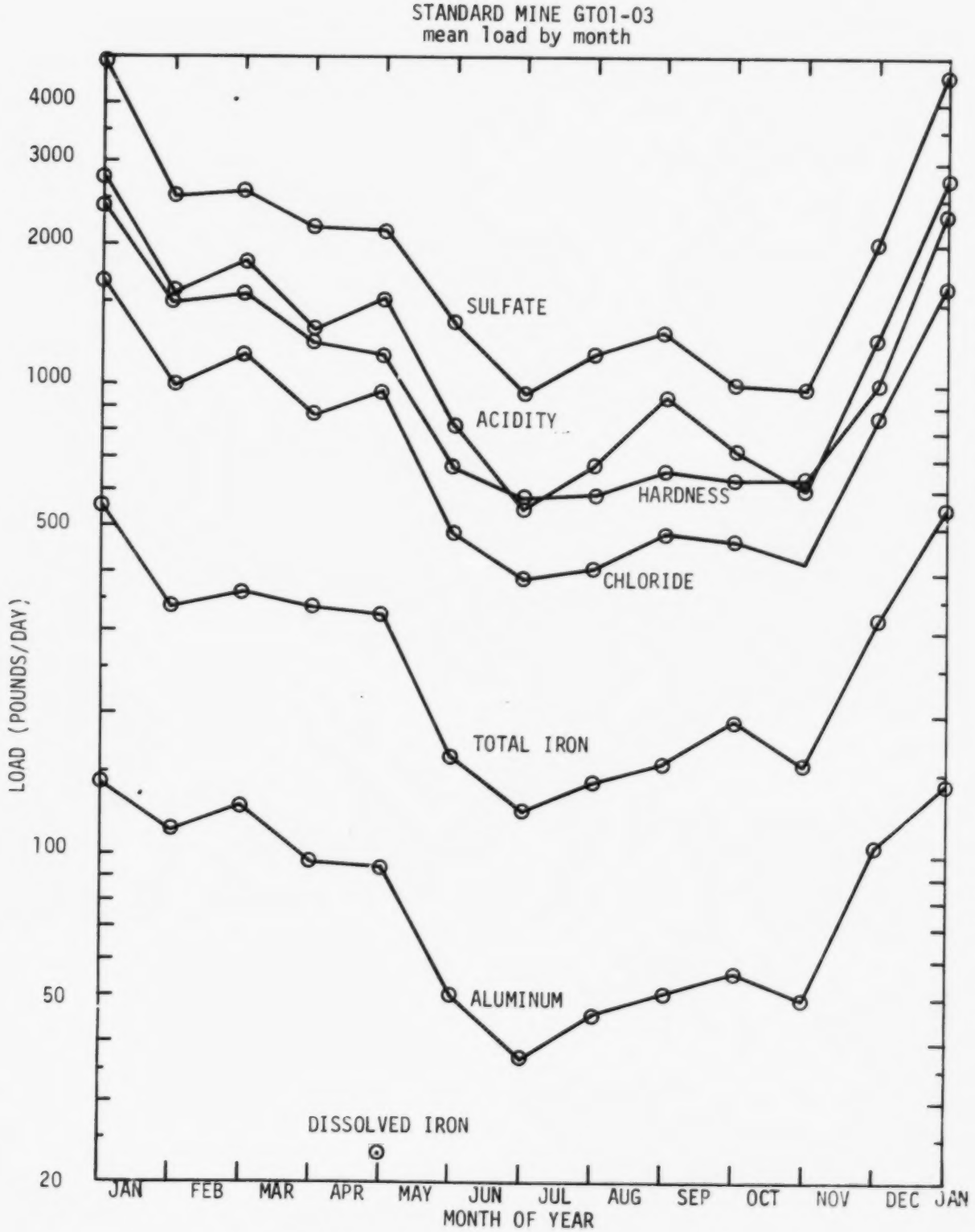

STANDARD MINE GT01-03
mean load by month
4000
3000
2000
1000
500
100
50
20
LOAD (POUNDS/DAY)
SULFATE
ACIDITY
HARDNESS
CHLORIDE
TOTAL IRON
ALUMINUM
DISSOLVED IRON
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
MONTH OF YEAR

FIGURE 11
STANDARD MINE GT06-01
mean load by month

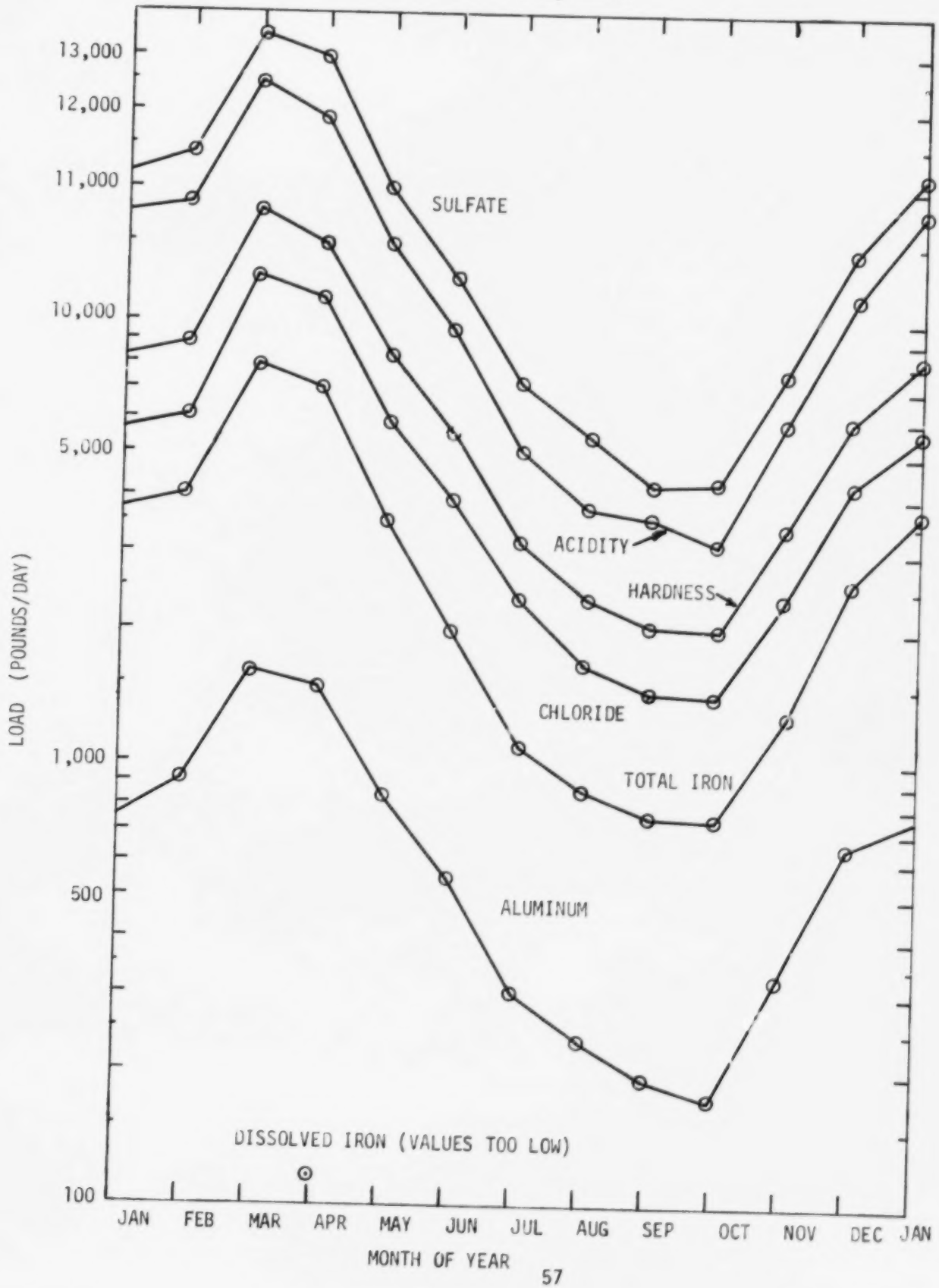
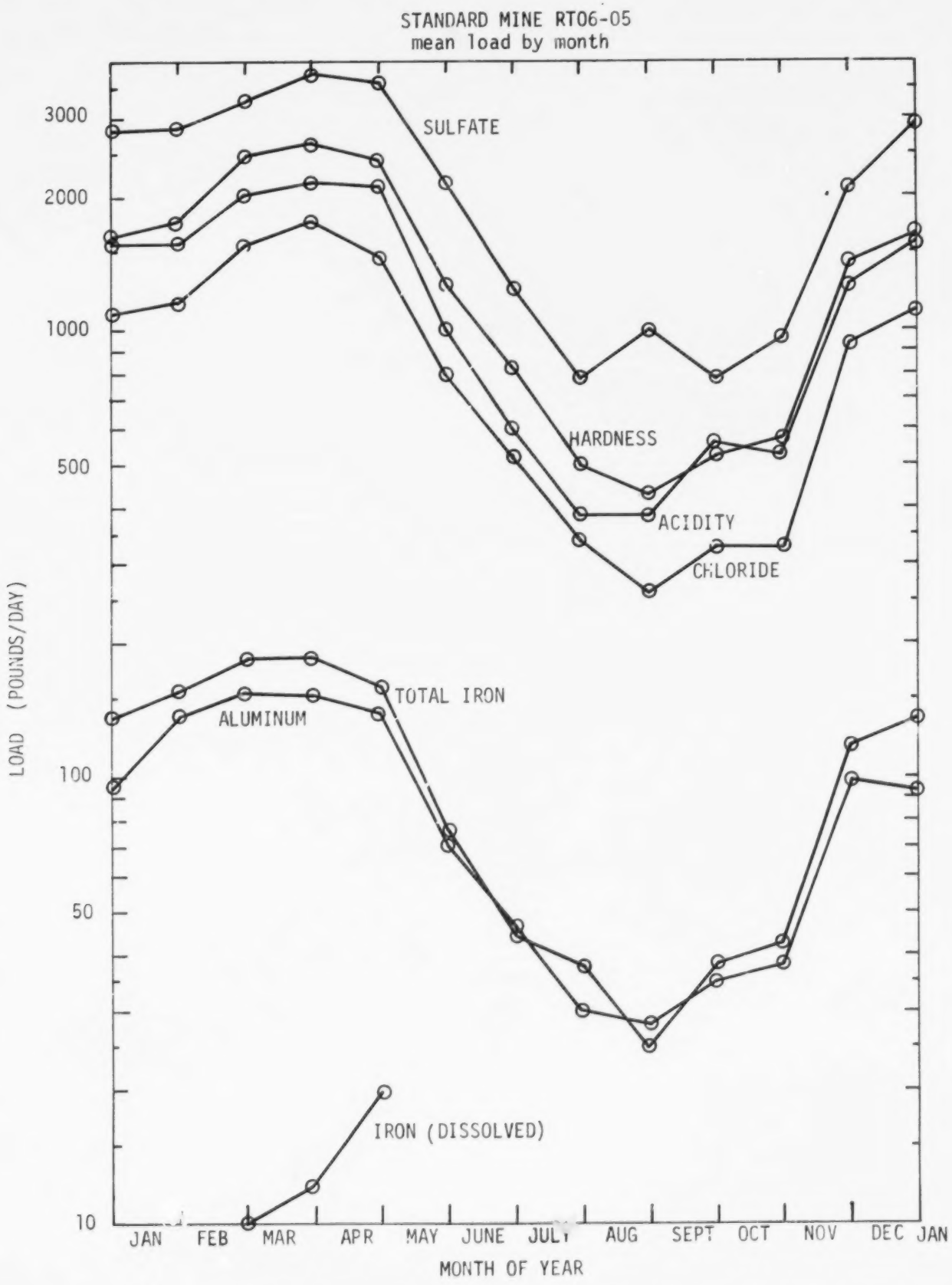


FIGURE 12



Note: Dissolved iron values too low to appear on graph in some cases.

FIGURE 11
STANDARD MINE GT06-01
mean load by month

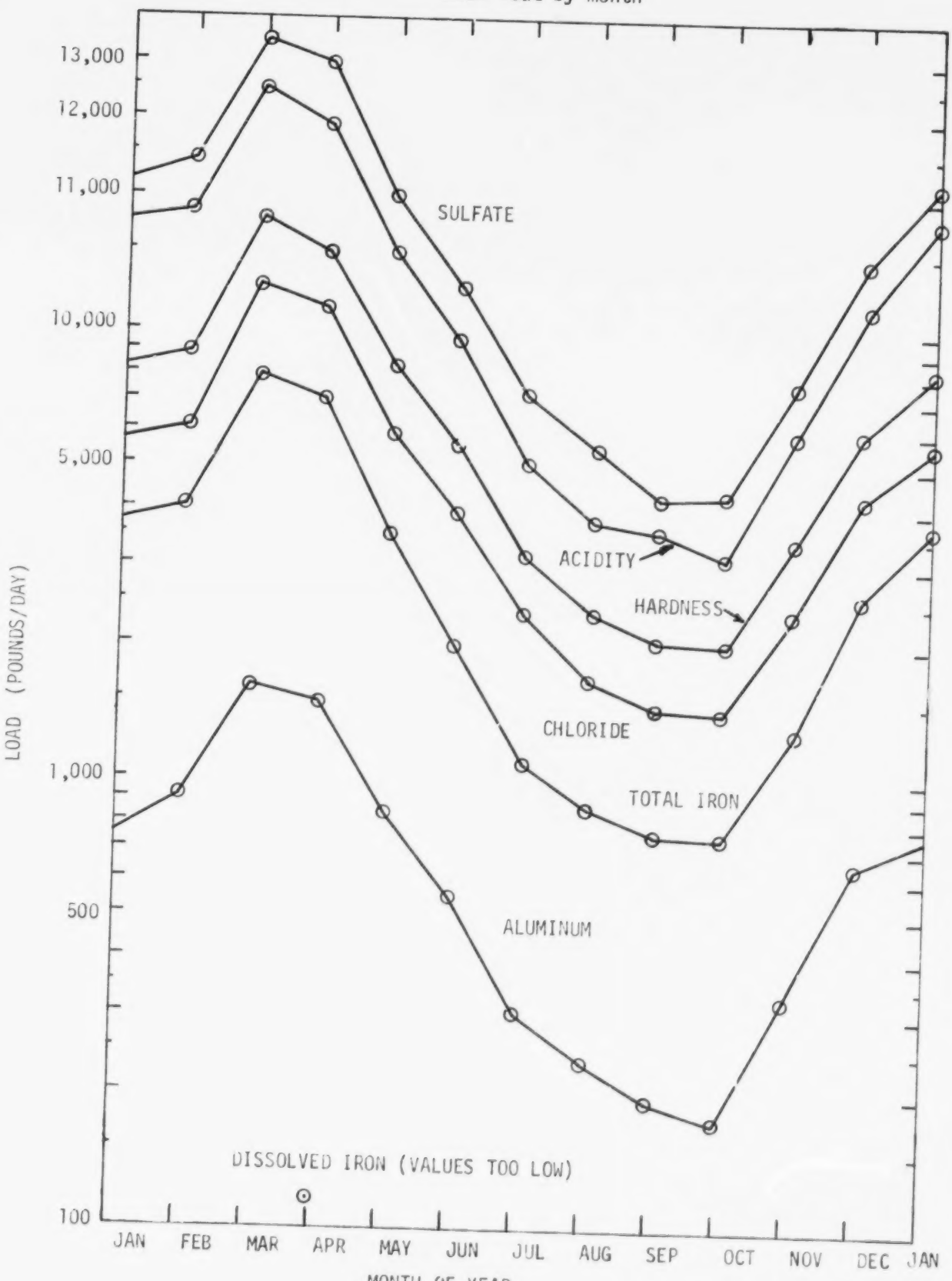


FIGURE 13

STANDARD MINE RT06-09
mean load by month

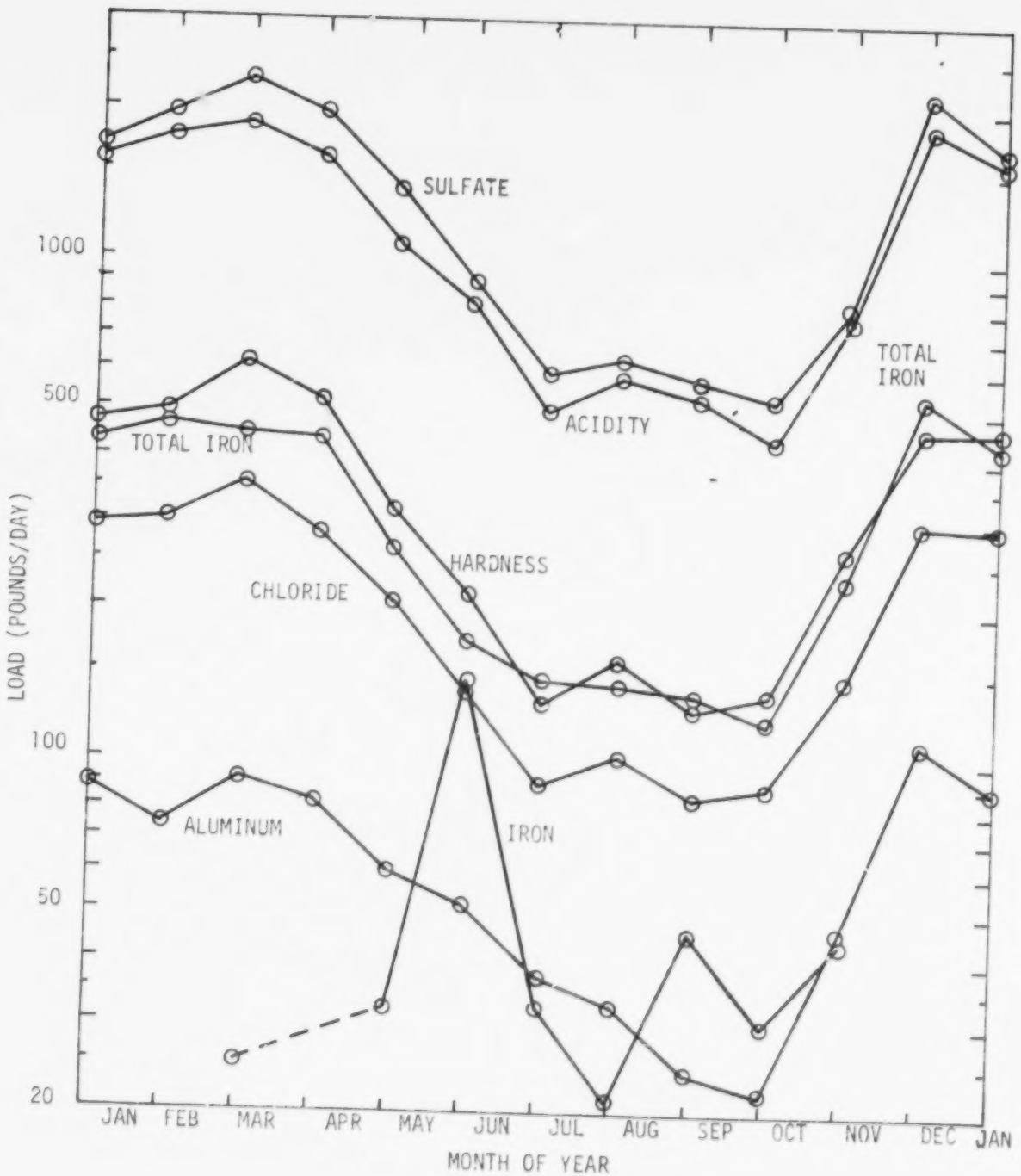
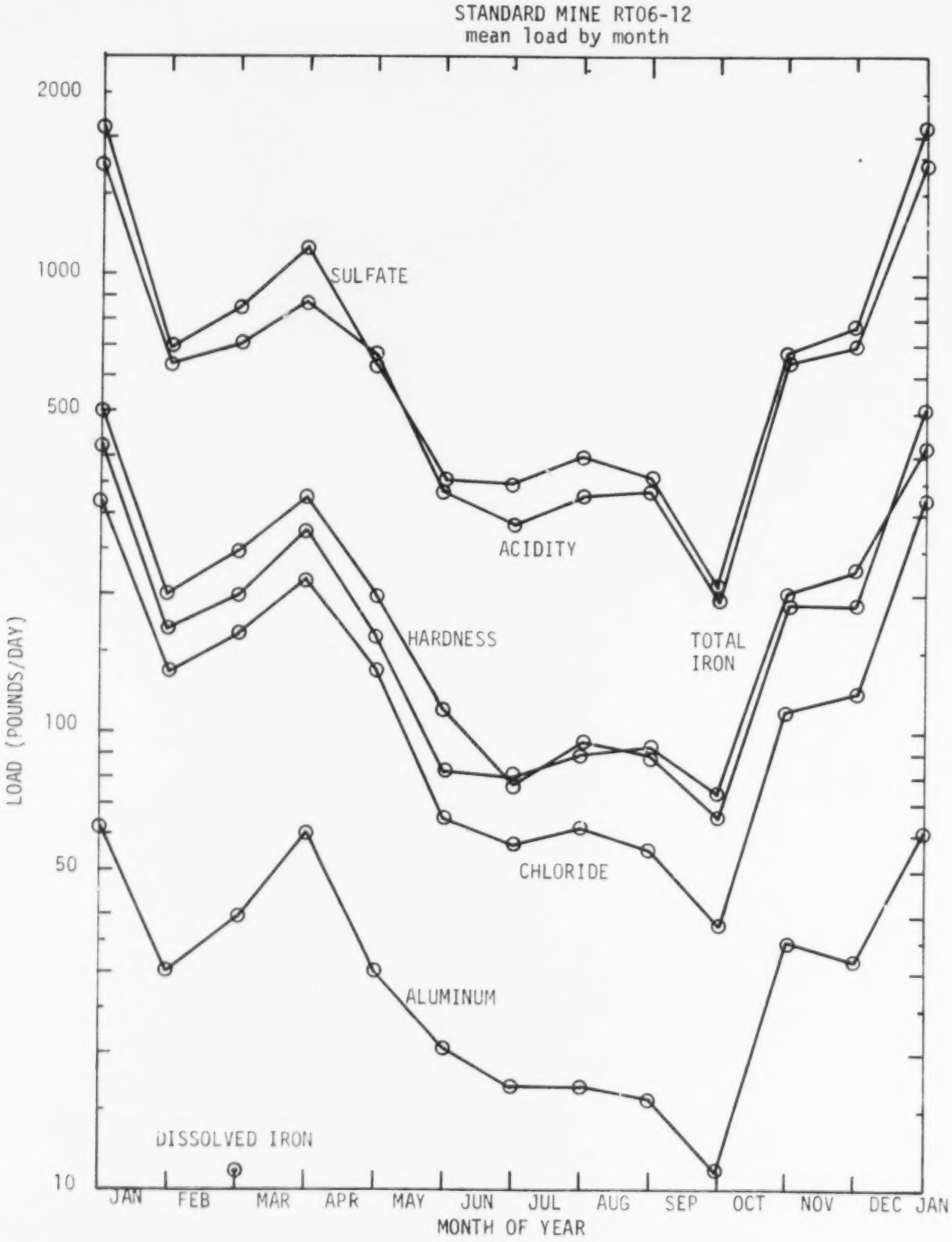


FIGURE 14



Note: Dissolved iron values too low to appear on the graph in most cases.

FIGURE 15

STANDARD MINE RT06-23
mean load by month

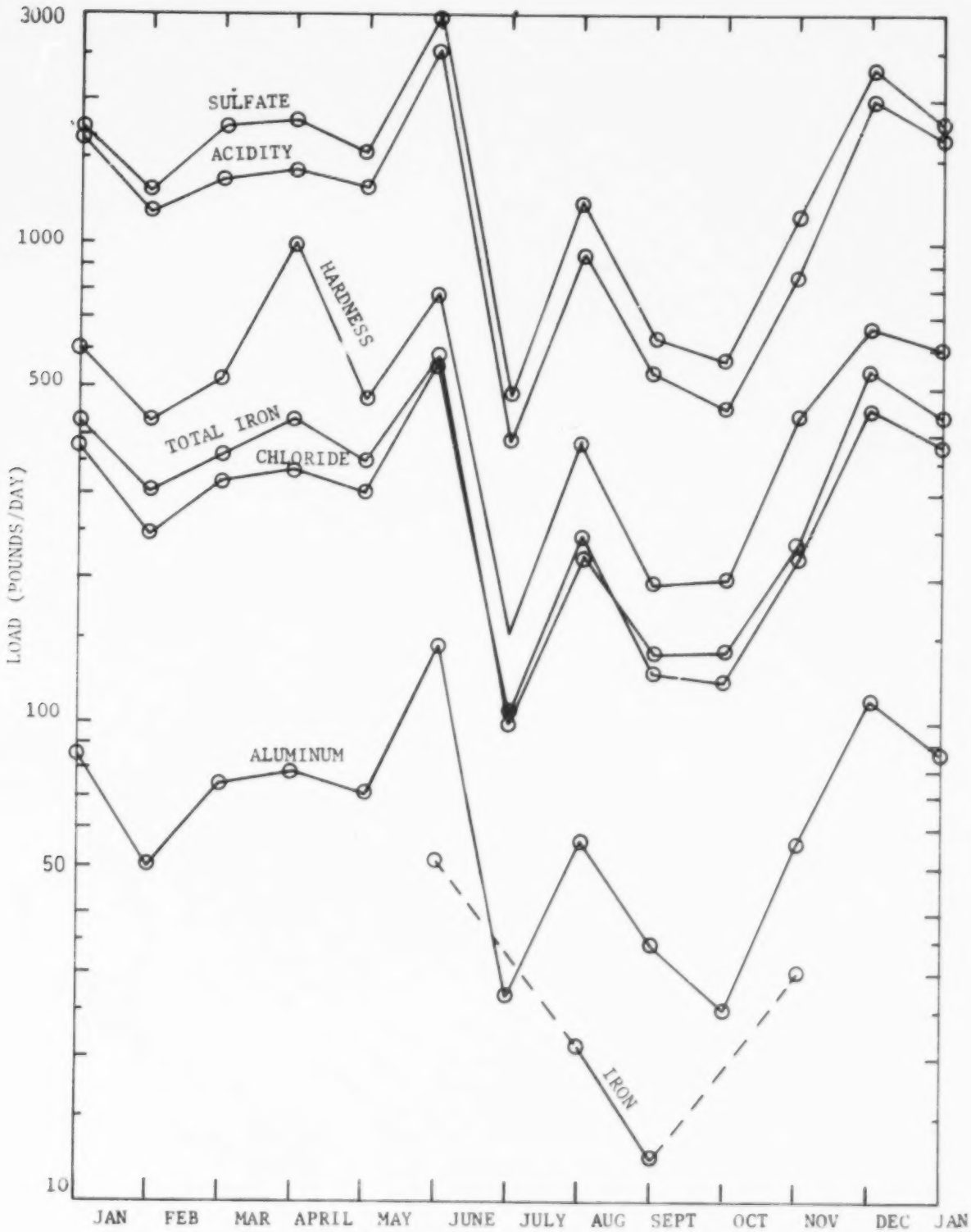


FIGURE 16

STANDARD MINE RT09-11
mean load by month

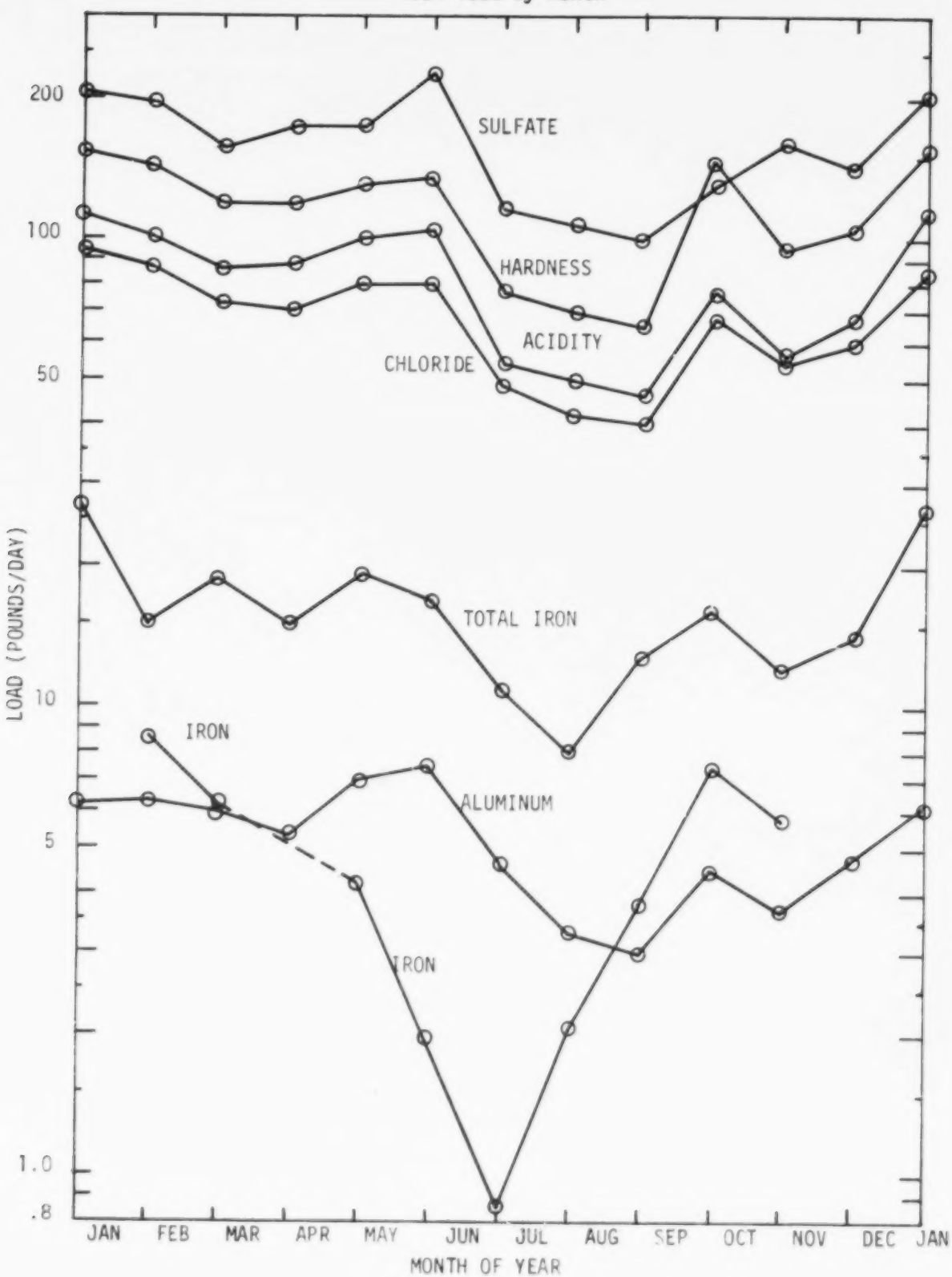
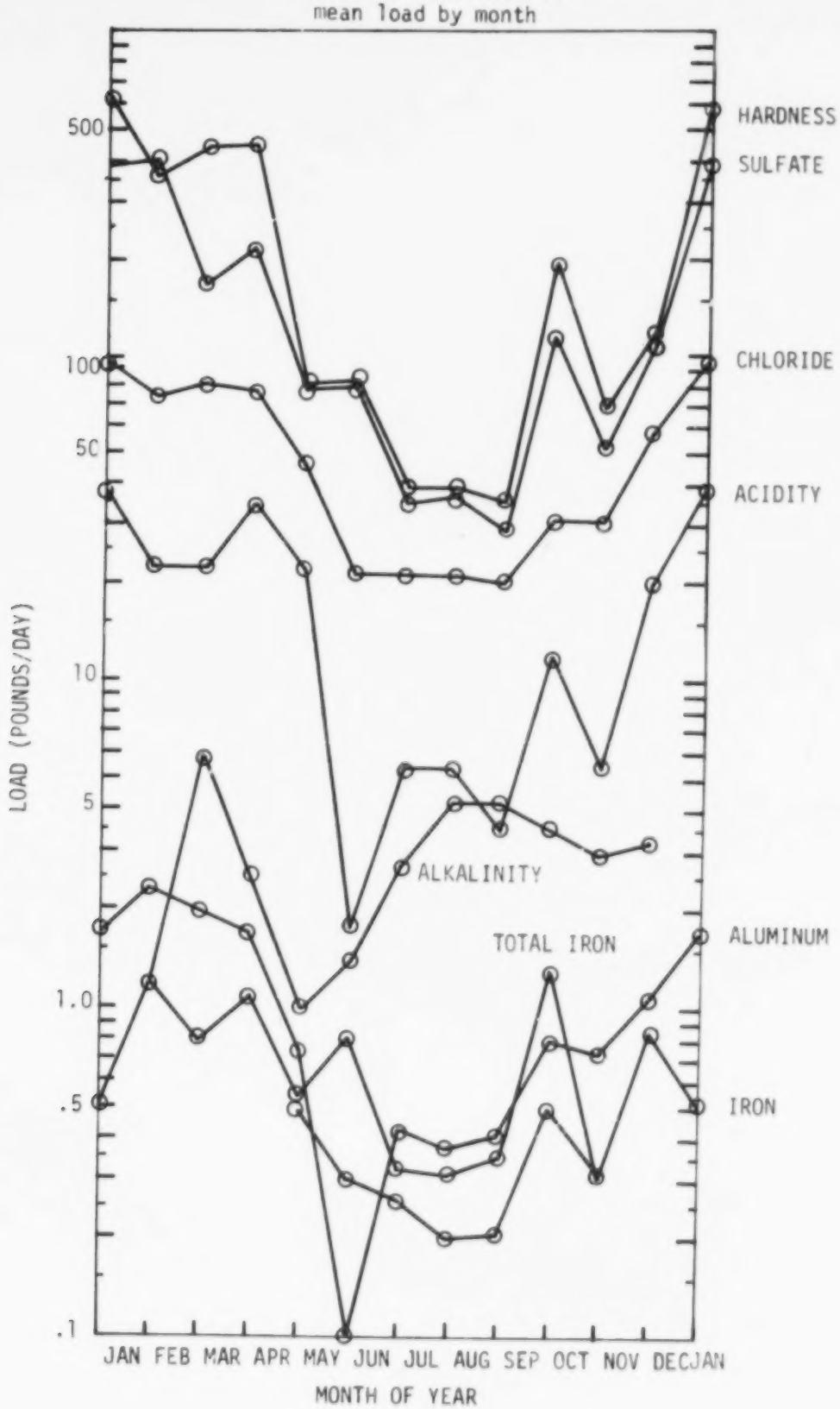


FIGURE 17

STANDARD MINE RT8B-03

mean load by month



They indicate that, within the ranges of flow represented by the data base, the long term (month-to-month) relationship between load and flow for a given pollutant is essentially linear.* This suggests that if one were able to establish the mean levels of concentration for the various pollutants, load could be determined thereafter using only flow information. Furthermore, if mine flow values can be established as being strongly related to some commonly monitored natural phenomenon, such as rainfall, then AMDC load can be determined with considerable accuracy for all pollutants with a minimum amount of field sampling. It would then be necessary to monitor flow and concentration directly only on an occassional basis to insure that the previously established relationships between them had not changed.

Table 5 is a ranking table of the magnitudes of the loads of the several pollutants by SM. The numbers in the table itself indicate the ranking of the loads by pollutant over the cyclical year for each SM. For example, the BC-01 row of Table 5 indicates that sulfate was the highest contributor of pollutant load over a cyclical year, hardness the second high load contributor, acidity third, total iron fourth, iron fifth and manganese sixth. The SM's are grouped according to families of SM's having similar load ranking characteristics. Thus, GT01-03 and GT06-01 belong to one family, BC-01 to a family by itself,

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* This same tendency was noted in an earlier study that considered only the SM's: Piper, Sagamore, Oneida, Florence I and Florence II. See: S. A. Braley (1).

TABLE 5

RANK OF POLLUTANT LOADS BY STANDARD MINE

MINE	ACIDITY	TOTAL IRON	SULFATE	HARDNESS	ALKALINITY	IRON	CHLORIDE	ALUMINUM	MANGANESE
Florence I	1					2			
Florence II	1					2			
Oneida	1					2			
Piper	1		2			3			
Sagamore	1					2			
GT01-03	2	5	1	3			4	6	7
GT06-01	2	5	1	3		7	4	6	8
BC-01	3	4	1	2		5			6
RT06-09	2	4	1	3		7	5	6	8
RT06-12	2	4	1	3		7	5	6	8
RT06-23	2	4	1	3		8	5	6	7
RT06-05	3	5	1	2		7	4	6	8
RT09-11	3	5	1	2		7	4	6	8
RT8B-03	4	7	2	1	5	8	3	6	9

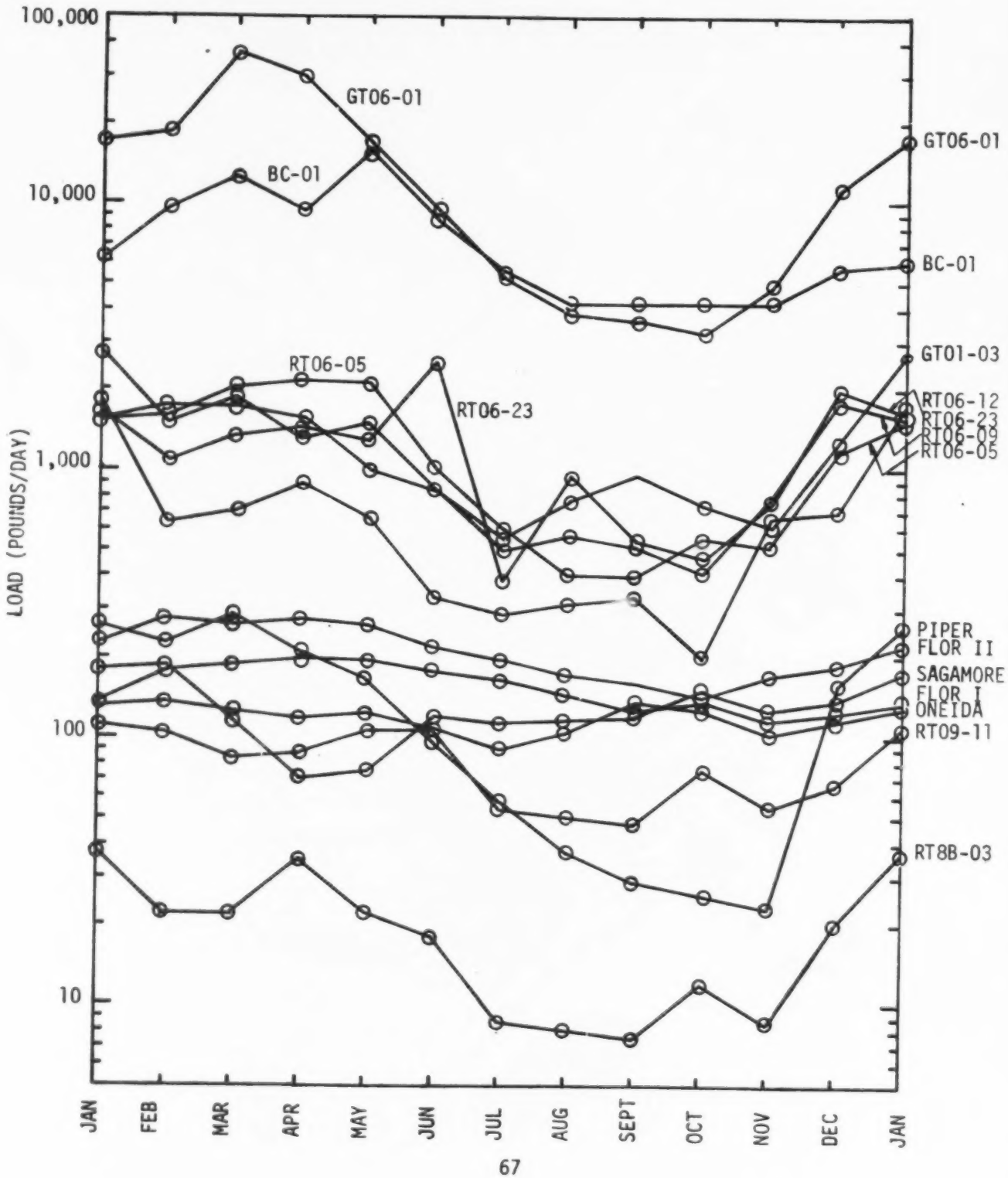
etc. Identification by family at this point is tentative because of the lack of homogeneity of the available data. Also, in order to be complete, a ranking table such as Table 5, which subtends a cyclical year, requires that the relative rankings of the loads of the several pollutants be consistent over a cyclical year. While this was generally true, there are a few notable exceptions as evidenced by Figures 4 through 17.

Figure 18 compares the time-load profiles for acidity for all 14 of the SM's. Again, the similarity of time-load profiles is evident, and the SM time-load profiles tend to group themselves into families. These families are similar to but not exactly equivalent to the ranking families presented in Table 5. The similarity of the load patterns of all pollutants with an individual SM make it evident that plots of other pollutants across all SM's would display characteristics similar to those of Figure 18.

Additional and more definitive analysis is required to definitely establish the existence of families of SM's and identify their members and characteristics. For this reason the SM's were treated individually throughout this analysis, although a stronger statistical base would have resulted from pooling data collected from SM's having similar time-load profiles and ranking patterns to form composite SM's.

FIGURE 18

ACIDITY FOR ALL STANDARD MINES
mean load by month



Synthesis of NSS Time-Load Profiles

The techniques for synthesizing NSS time-load profiles described in Chapter III were applied to all available NSS data. Out of some 7,000 known NSS locations in the Monongahela Basin, available data indicated that over 4,700 of the total number were dry - having no significant contribution to acid mine drainage contamination in the Basin. The NSS time-load synthesis techniques were applied to the remaining 2,300, or so,NSS to synthesize time-load profiles for each pollutant on which there was data. No time-load profiles were generated for alkalinity or manganese because of the paucity of data relating to these two pollutants. For some of the 2,300 which were processed, no flow values were recorded in the field.

Examples of the results produced by the NSS time-load profile synthesis procedure are shown in Tables 6, 7 and 8. Data for NSS 080111, the same NSS used in the illustrative example of Chapter III, is presented in Table 6. It may be noted that data exist only for Sulfate, Acidity, Total Iron, Hardness and Aluminum both, in the case of NSS 080111 and NSS 080171 (Table 7). The totality of all of the synthesized NSS time-load profiles is contained in Volume III of this report.

TABLE 6

NSS TIME-LOAD PROFILE SYNTHESIS RESULTS FOR
NON-STANDARD SOURCE NO. 080111*

Pollutants/ S. Source	January	February	March	April	May	June
ACIDITY GT01-03	1.254E+01	7.073E+00	8.227E+00	5.869E+00	6.847E+00	3.749E+00
TOTAL IRON GT06-12	2.739E-01	1.071E-01	1.249E-01	1.745E-01	1.030E-01	5.178E-02
SULFATE GT01-03	2.442E+01	1.238E+01	1.274E+01	1.062E+01	1.101E+01	6.593E+00
HARDNESS BC-01	4.735E+01	1.198E+02	0.000E+00	0.000E+00	1.048E+02	5.536E+01
ALUMINUM GT01-03	7.154E-02	5.652E-02	6.518E-02	4.879E-02	4.772E-02	2.532E-02

* Loads by month (lbs/day) Best fit of NSS 080111 Maryland Minor (sub)basin 29

TABLE 6 (Continued)

NSS TIME-LOAD PROFILE SYNTHESIS RESULTS FOR

NON-STANDARD SOURCE NO. 080111*

Pollutants/ S. Source	July	August	September	October	November	December
ACIDITY GT01-03	2.495E+00	3.060E+00	4.264E+00	3.298E+00	2.746E+00	5.606E+00
TOTAL IRON GT06-12	5.068E-02	5.644E-02	5.863E-02	4.657E-02	1.276E-01	1.413E-01
SULFATE GT01-03	4.713E+00	5.836E+00	6.398E+00	5.372E+00	4.884E+00	9.939E+00
HARDNESS BC-01	1.491E+01	1.041E+01	1.079E+01	1.236E+01	0.000E+00	3.892E+01
ALUMINUM GT01-03	1.917E-02	2.353E-02	2.611E-02	2.912E-02	2.511E-02	5.387E-02

* Loads by month (lbs/day) Best fit of NSS 080111 Maryland Minor (sub)basin 29

TABLE 7

NSS TIME-LOAD PROFILE SYNTHESIS RESULTS FOR

NON-STANDARD SOURCE NO. 080171*

Pollutants/ S. Source	January	February	March	April	May	June
ACIDITY. FLOR-2	2.286E+02	2.755E+02	2.693E+02	2.785E+02	2.625E+02	2.186E+02
TOTAL IRON RT8B-03	1.914E+00	4.790E+00	2.978E+00	4.450E+00	2.044E+00	3.102E+00
SULFATE RT09-11	3.844E+02	3.655E+02	2.898E+02	3.202E+02	3.190E+02	4.147E+02
HARDNESS RT06-12	6.147E+02	2.372E+02	2.938E+02	3.885E+02	2.391E+02	1.327E+02
ALUMINUM RT06-12	3.879E+01	1.904E+01	2.428E+01	3.832E+01	1.962E+01	1.357E+01

* Loads by month (lbs/day) Best fit of NSS 080171 Maryland Minor (sub)basin 29

TABLE 7 (Continued)

NSS TIME-LOAD PROFILE SYNTHESIS RESULTS FOR

NON-STANDARD SOURCE NO. 080171*

Pollutants/ S. Source	July	August	September	October	November	December
ACIDITY FLOR-2	1.957E+02	1.726E+02	1.644E+02	1.463E+02	1.657E+02	1.895E+02
TOTAL IRON RT8B-03	1.318E+00	1.224E+00	1.330E+00	5.148E+00	1.125E+00	3.200E+00
SULFATE RT09-11	2.152E+02	2.006E+02	1.876E+02	2.414E+02	2.160E+02	2.637E+02
HARDNESS RT06-12	9.159E+01	1.143E+02	1.057E+02	7.807E+01	2.299E+02	2.274E+02
ALUMINUM RT06-12	1.074E+01	1.113E+01	9.891E+00	7.215E+00	2.207E+01	2.017E+01

* Loads by month (lbs/day) Best fit of NSS 080171 Maryland Minor (sub)basin 29

It is of interest to review the selections of standard mines which were made by the program generating the NSS profiles. To produce the synthesized profile in Table 6 (080111) the program selected the following SM curves (profiles) as being most nearly representative of the NSS 080111 (left hand column of Table 6):

Acidity from	SM GT01-03
Total Iron from	SM GT06-12
Sulfate from	SM GT01-03
Hardness from	SM BC-01
Aluminum from	SM GT01-03

For data synthesis on NSS 080111, the program used GT01-03 three times; for Acidity, Sulfate and Aluminum.

For profile synthesis for NSS 080171 the selections were as follows (left hand column of Table 7):

Acidity from	SM Florence II
Total Iron from	SM RT8B-03
Sulfate from	SM RT09-11
Hardness from	SM RT06-12
Aluminum from	SM RT06-12

The selections were different from those in 080111 and a single mine was duplicated only once, in the case of RT06-12.

Only one non-zero flow value was available for both of these mine openings.

Table 8 presents the synthesizing results for NSS 090111. Two non-zero flow measurements were available for this mine opening.

TABLE 8

NSS TIME-LOAD PROFILE SYNTHESIS RESULTS FOR

NON-STANDARD SOURCE NO. 090011*

Pollutants/ S. Source	January	February	March	April	May	June
ACIDITY FLOR-1	2.509E+04	3.310E+04	3.510E+04	3.623E+04	3.603E+04	3.267E+04
TOTAL IRON RT09-11	2.283E+04	1.326E+04	1.644E+04	1.338E+04	1.682E+04	1.443E+04
SULFATE RT09-11	1.439E+05	1.369E+05	1.085E+05	1.199E+05	1.194E+05	1.553E+05
HARDNESS RT09-11	4.846E+04	4.633E+04	3.828E+04	3.809E+04	4.187E+04	4.269E+04
ALUMINUM RT06-05	6.766E+02	9.859E+02	1.099E+03	1.094E+03	1.000E+03	5.163E+02

* Loads by month (lbs/day) Best fit of NSS 090011 Pennsylvania Minor (sub)basin 24

TABLE 8 (Continued)

NSS TIME-LOAD PROFILE SYNTHESIS RESULTS FOR

NON-STANDARD SOURCE NO. 090011*

Pollutants/ S. Source	July	August	September	October	November	December
ACIDITY FLOR-1	3.106E+04	2.705E+04	2.348E+04	2.532E+04	2.165E+04	2.328E+04
TOTAL IRON RT09-11	9.978E+03	6.850E+03	1.164E+04	1.372E+04	1.057E+04	1.217E+04
SULFATE RT09-11	8.061E+04	7.514E+04	7.025E+04	9.040E+04	8.090E+04	9.875E+04
HARDNESS RT09-11	2.457E+04	2.239E+04	2.084E+04	4.739E+04	3.014E+04	3.339E+04
ALUMINUM RT06-05	3.248E+02	2.239E+02	2.043E+02	2.571E+02	2.733E+02	7.105E+02

* Loads by month (lbs/day) Best fit of NSS 0900011 Pennsylvania Minor (sub)basin 24

Pollutant Load Ranking by Monongahela Subbasins

Table 9 is a reproduction of one page of the Source Ranking by Acidity Load Report. The data in this table are for all the sources in 10 Mile Creek, Pennsylvania synthesized for the month of December (cyclical). This information is presented in detail in Volume IV of this report. The average load (lbs/day) for each pollutant on which data were available, segregated by cyclical month, source and subbasin, is tabulated in this report. Within each subbasin and cyclical month, the sources are ranked in the order of their acidity load. Cumulative, as well as individual source loads are shown for each pollutant.

Standard mines and all non-standard sources having one lb/day or more of acid load are included in Volume IV. The total number of sources included in the Source Ranking by Acidity Load Report is 1,650 (see Table 10). Thus, the low cutoff point of one lb. of acidity load per day had the effect of eliminating 648 active sources from this report. The number of contributing sources counted in the Source Ranking by Acidity Load Report varies somewhat from month to month. This results from the fact that some sources have average loads of one lb/day (or 100 lbs/day) during some months, and hence, are included for that month, but have loads of less than one lb/day (or 100 lbs/day) during other months.

Volume IV of this report contains data for all of the 30 subbasins in the Monongahela River Basin with the exception of subbasins numbered 7,17 and 21, in which cases, according to available data, no

TABLE 9

SOURCE RANKING BY ACIDITY LOAD FOR MONTH OF DECEMBER
(lbs/day)

Monongahela River Sub-Basin Code-3 10 Mile Creek, Pennsylvania Including South Fork

Rank	NSS	Acidity Load	Acidity Cum	Total Iron Load	Total Iron Cum	Sulfate Load	Sulfate Cum	Hardness Load	Hardness Cum	Aluminum Load	Aluminum Cum
1	120041	10,790	10,790	4,153	4,153	19,980	19,980	3,328	3,328	699	699
2	010091	187	10,977	107	4,260	2,232	22,212	1,476	4,804		699
3	210441	183	11,160	24	4,284	2,168	24,380	956	5,760	5	704
4	010031	179	11,339	4	4,288	256	24,636	114	5,874	16	720
5	010094	135	11,474	13	4,301	1,193	25,829	869	6,743	24	744
6	010011	130	11,604	10	4,311	147	25,976	32	6,775	4	748
7	210641	122	11,726	564	4,875	142	26,118	1,541	8,316	110	858
8	210241	102	11,828	2	4,877	48	26,166	28	8,344	3	861
9	210201	75	11,903	15	4,892	121	26,287	49	8,393	2	863
10	210231	23	11,926		4,892	92	26,379	102	8,495	1	864
11	210251	18	11,944	5	4,897	9	26,388	34	8,529	3	867
12	210401	7	11,951	19	4,916	639	27,027	588	9,117	1	868
13	210091	6	11,957		4,916	11	27,038	11	9,128		868
14	120081	6	11,963		4,916	10	27,048	5	9,133		868
15	360051	6	11,969	1	4,917	12	27,060	4	9,137	1	869
16	210291	4	11,973		4,917	6	27,066	2	9,139		869
17	120061	2	11,975		4,917	4	27,070	1	9,140		869
18	010041	2	11,977		4,917	5	27,075	2	9,142		869
19	120101	1	11,978		4,917	2	27,077	1	9,143		869
20	120211	1	11,979		4,917	5	27,082	19	9,162		869
21	120201	1	11,980		4,917	4	27,086	4	9,166		869
22	210141	1	11,981		4,917	3	27,089		9,166		869
23	210381	1	11,982		4,917	4	27,093	4	9,170		869
24	210321	1	11,983		4,917	9	27,102	32	9,202		869
25	210301	1	11,984		4,917	9	27,111	27	9,229		869
26	360101	1	11,985	1	4,918	16	27,127	28	9,257		869

TABLE 10

SUMMARY OF THE NUMBER OF SOURCES CONTRIBUTING TO ACIDITY LOAD OF 1 LB/DAY OR GREATER*

Sub-Basin Number	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average Number of Mines (Monthly)
1	180	177	176	180	177	176	161	161	157	169	161	176	171
2	16	16	16	16	16	15	12	12	11	14	12	15	14
3	31	26	26	30	27	25	16	16	115	21	16	26	23
4	159	154	154	159	154	154	146	146	140	150	146	154	151
5	31	31	30	31	31	30	28	29	28	30	29	30	30
6	51	51	51	51	51	51	51	51	50	50	50	51	51
7													
8	265	262	262	263	262	261	225	229	209	252	231	261	249
9	76	72	71	76	72	71	64	65	55	71	65	71	69
10	4	3	3	4	3	3	3	3	3	3	3	3	3
11	121	118	117	121	118	115	96	96	87	108	96	115	109
12	20	19	19	19	19	19	15	15	15	18	15	19	18
13	27	26	26	27	26	26	23	23	22	26	23	26	25
14	116	87	86	111	87	81	35	36	25	61	36	82	62
15	47	41	41	46	42	39	18	18	12	34	18	39	33
16	7	7	7	7	7	7	7	7	7	7	7	7	7
17													
18	53	53	53	53	53	53	49	49	49	52	49	53	52
19	17	16	16	16	16	16	15	15	15	15	15	16	14
20	6	6	6	6	6	5	5	5	5	5	5	5	5
21													
22	35	33	33	35	34	33	28	28	25	30	28	33	31
23	164	160	160	164	161	157	137	137	124	151	137	158	151
24	84	82	82	84	82	81	78	78	78	81	78	81	81
25	27	26	26	26	26	26	26	24	23	26	24	26	26
26	53	53	53	53	53	52	45	45	43	49	45	52	50
27	23	21	21	22	21	20	18	18	14	20	18	21	20
28	7	7	7	7	7	7	5	5	5	6	5	7	6
29	169	161	160	168	161	155	130	132	121	151	132	158	150
30	38	38	38	38	38	38	36	36	36	36	36	38	37

Total: 1,637 + 13 (SM) = 1,650

* Based on Volume IV, SM's are not included in the monthly totals for subbasins, but are added to the final total. SM BE-01 is not in the Monongahela Basin.

AMDC sources contributing greater than one lb/day of acid load are located.

Table 11 summarizes the acid load values of the Source Ranking by Acidity Load Report (Volume IV). It contains average acid load by month as well as the average acidity load over all months for each subbasin. It is apparent from Table 11 that the, "high in winter, low in late summer", seasonal load patterns displayed by the SM's were maintained throughout all of the subbasins. This is, of course, to be expected since the time-load vectors of the NSS are, by design, those of the SM's, and the similarity of the load patterns across SM's has already been described.

Table 12 summarizes the Source Ranking by Acidity Load Report (Volume IV) except the data presented includes only those mines having average acidity load values $\geq$ 100 lb/day.

Table 13 presents results of a source analysis on a monthly basis similar to what is presented in Table 10, except that the results in Table 13 are for those sources having average acidity load values $\geq$ 100 lb/day, also.

It may be noted that the total normal average acidity load over all subbasins, from Table 11 is 1,156,364 lbs/day. The comparable value from Table 12 is 1,132,523 lbs/day. The number of AMDC sources contributing to the total of Table 11 was 1,650. The number of sources contributing to the total of Table 12 was 599. Thus, the elimination of 36.3 percent of the AMDC sources within the Monongahela River Basin will eliminate 98 percent of the

TABLE 11

AVERAGE ACIDITY LOAD (LBS/DAY) BY MONTH AND SUBBASIN *

Sub-Basin Number	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. Annual Acid Load (Lbs/day)
1	73,516	58,467	68,465	69,126	64,604	45,227	22,623	21,968	20,553	22,951	24,724	51,864	45,341
2	118,983	179,704	238,455	178,466	276,672	154,618	91,605	72,940	73,939	76,266	78,772	105,181	137,133
3	12,916	20,376	25,373	19,074	31,790	18,202	11,107	8,904	8,904	9,360	9,336	11,985	15,611
4	142,352	134,170	188,053	166,083	137,415	106,996	50,176	51,406	44,141	42,127	60,593	113,284	103,066
5	134,824	170,850	216,369	165,199	232,956	134,265	77,249	60,903	58,755	61,594	62,337	110,007	123,776
6	185,000	176,231	213,924	163,802	233,584	137,599	80,653	75,839	83,452	77,432	78,531	125,537	135,967
7													
8	88,637	79,539	100,220	93,156	81,259	59,282	31,672	30,685	28,160	30,260	35,302	65,977	60,345
9	12,827	10,238	10,859	11,565	10,502	9,070	5,343	5,453	4,896	5,048	5,976	9,181	8,413
10	1,172	1,155	1,423	1,547	1,496	754	477	300	296	440	395	908	861
11	29,820	29,071	47,552	40,420	25,409	17,783	8,620	7,638	6,711	7,288	9,779	20,813	20,908
12	1,032	1,018	869	880	850	874	651	615	565	764	588	734	787
13	8,080	4,964	5,490	4,477	4,672	2,953	1,846	2,089	2,638	2,427	1,932	3,887	3,788
14	1,286	945	778	986	748	748	374	381	347	633	407	731	697
15	4,929	7,809	9,872	7,449	12,578	7,049	4,135	3,278	3,290	3,511	3,481	4,559	5,995

* Summary of the Source Ranking by Acidity Load Report (Volume IV). Summary for all mines, including SM's having an acidity load of 1 lb/day or greater.

TABLE 11 (Continued)

Sub-Basin Number	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. Annual Acid Load (lbs./day)
16	31,356	28,409	46,971	40,512	26,183	17,009	8,774	7,950	7,434	6,993	10,921	20,993	21,125
17													
18	56,254	55,823	86,616	73,584	55,264	35,300	19,204	16,952	15,698	15,475	22,632	40,564	41,114
19	1,179	784	726	1,042	806	709	265	263	206	501	275	632	616
20	527	462	488	369	305	247	160	140	131	169	130	326	288
21													
22	8,969	10,043	12,140	9,828	13,704	8,135	5,082	4,265	4,257	4,367	4,655	6,550	7,666
23	92,501	100,100	144,434	120,120	114,129	73,439	41,842	36,506	34,809	34,908	43,003	69,077	75,406
24	262,376	328,212	415,806	333,012	440,908	272,215	164,723	136,354	128,945	135,536	136,419	218,885	247,783
25	9,059	7,125	8,275	8,452	7,618	6,806	2,817	3,093	2,415	2,698	3,283	6,955	5,716
26	35,003	53,476	66,865	50,250	82,556	46,860	27,742	22,246	22,251	23,578	23,681	32,176	40,557
27	3,410	1,905	1,947q	2,171	1,851	1,301	899	985	1,070	1,035	1,359	1,715	1,637
28	320	182	179	294	186	155	40	41	26	103	41	164	144
29	57,868	44,084	49,678	51,254	46,962	43,317	18,390	21,573	18,223	18,501	23,404	44,896	36,508
30	23,981	21,270	33,591	27,462	17,924	11,075	6,251	5,770	6,060	5,541	7,184	15,288	15,116
												TOTAL:	1,156,364

TABLE 12

ACID LOAD (LBS/DAY) FOR MINES HAVING AN AVERAGE LOAD ≥ 100 LB/DAY*

Sub-Basin Number	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. Monthly Acid Load (lbs/day)
1	71,140	55,973	65,471	65,209	61,046	40,779	18,639	18,744	18,368	20,013	21,797	47925	42,088
2	118,711	179,519	238,285	178,225	276,483	154,452	91,542	72,878	73,890	76,149	78,707	105,037	136,990
3	12,746	20,284	25,100	18,700	31,565	18,036	10,883	8,701	8,718	9,197	9,136	11,828	15,408
4	140,368	132,788	186,559	163,604	135,450	105,162	48,188	49,757	42,860	40,460	59,134	111,600	101,328
5	134,421	170,592	216,082	164,802	232,650	134,043	76,834	60,491	58,385	61,233	61,948	109,630	123,426
6	184,032	175,462	213,219	162,796	232,632	136,613	79,901	75,383	83,145	76,859	78,060	124,834	135,245
7													
8	84,498	75,976	96,064	87,271	76,853	54,942	27,821	27,422	25,838	26,665	32,193	62,125	56,472
9	11,721	9,327	9,994	10,074	9,364	8,064	4,570	4,901	4,515	4,449	5,435	8,458	8,204
10	1,075	1,072	1,352	1,469	1,410	671	405	260	260	378	352	852	796
11	27,675	27,468	45,820	37,604	23,463	15,991	7,177	6,419	5,808	5,825	8,695	19,256	19,283
12	818	897	561	455	589	774	410	376	448	524	440	475	564
13	7,641	4,539	5,082	4,010	4,157	2,583	1,580	1,844	2,450	1,978	1,692	3,438	3,416
14	455	468	126	102	121	246	116	121	126	282	234	252	312
15	4,570	7,559	9,601	7,088	12,272	6,836	3,977	3,146	3,173	3,311	3,342	4,268	5,762

* Summary of the Source Ranking by Acidity Load Report (Volume IV) for all mines, including SM's having acidity loads of 100 lb/day or greater. It should be noted that SM BC-01 is not in the Monongahela River Basin and SM's RT8B-03 and RT09-11 possess average daily acidity loads less than 100 lb/day.

TABLE 12 (Continued)

ACID LOAD (LBS/DAY) FOR MINES HAVING AN AVERAGE LOAD ≥ 100 LB/DAY

Sub-Basin Number	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg. Monthly Acid Load (lbs/day)
16	31,196	28,253	46,644	40,227	25,970	16,787	8,604	7,777	7,277	6,827	10,736	20,785	20,924
17													
18	55,642	54,677	85,514	72,579	53,803	34,126	18,558	16,351	15,249	14,455	22,040	39,314	40,192
19	878	880	216	692	450	127	--	--	--	--	--	102	234
20	452	419	357	248	205	121	--	--	--	113	--	289	184
21													
22	8,472	9,733	11,665	9,204	13,291	7,780	4,288	3,749	3,912	3,847	4,214	6,043	7,183
23	90,418	98,575	141,551	116,723	111,790	70,917	38,971	33,910	32,939	32,855	40,786	67,221	73,055
24	260,791	326,718	413,491	330,942	439,351	270,585	163,624	135,585	128,361	134,328	135,671	217,391	246,402
25	8,202	6,548	7,743	7,621	6,935	6,121	2,275	2,671	2,084	2,165	2,936	6,399	5,142
26	34,196	52,744	65,707	49,130	81,603	45,523	26,604	21,333	21,479	22,724	22,820	30,776	39,553
27	3,078	1,582	1,551	1,796	1,423	839	331	691	898	702	969	1,283	1,262
28	206	--	--	--	--	--	--	--	--	--	--	--	17
29	56,092	42,726	47,578	48,590	44,712	40,681	16,325	19,914	16,819	17,285	21,793	42,881	34,610
30	23,361	20,598	32,944	26,804	17,237	10,252	5,469	5,190	5,690	4,980	6,687	14,437	14,471
											TOTAL:		1,132,523

TABLE 13

SUMMARY OF THE NUMBER OF SOURCES CONTRIBUTING TO ACIDITY LOAD OF 100 LBS/DAY, OR GREATER.*

Sub-Basin Number	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average Number of Mines (Monthly)
1	106	93	86	86	82	64	38	41	47	54	41	71	67
2	5	5	5	5	5	5	5	5	5	5	5	5	5
3	9	9	7	6	7	8	6	6	6	7	6	8	7
4	98	96	94	89	89	89	73	73	74	76	72	90	84
5	20	21	21	20	21	21	17	16	16	17	16	19	19
6	34	33	33	32	31	30	27	30	31	31	30	32	31
7													
8	117	107	97	88	95	94	68	71	76	80	71	94	88
9	27	25	25	21	22	23	19	21	22	23	21	25	23
10	1	1	1	1	1	1	1	1	1	1	1	1	1
11	27	24	22	19	20	19	9	9	10	11	9	21	17
12	6	6	4	3	4	6	3	3	4	4	4	4	4
13	9	7	7	8	6	7	4	4	4	4	4	6	6
14	3	3	1	1	1	2	1	1	1	2	2	2	2
15	2	2	2	2	2	3	1	1	1	1	1	1	2
16	12	11	9	10	10	10	9	9	9	10	9	10	10
17													
18	35	25	25	29	21	23	18	18	18	19	18	22	23
19	6	3	2	5	4	1	--	--	--	--	--	1	2
20	2	2	1	1	1	1	--	--	--	1	--	2	1
21													
22	14	14	12	12	13	13	4	6	7	7	6	11	10
23	77	75	59	56	63	63	42	43	48	55	46	66	58
24	50	44	42	42	43	41	34	37	37	38	37	41	41
25	13	13	13	12	12	11	8	8	8	8	8	12	11
26	24	21	16	19	18	11	4	5	5	9	5	12	12
27	8	7	6	7	6	5	1	4	5	5	3	5	5
28	2	--	--	--	--	--	--	--	--	--	--	--	--
29	79	74	65	62	60	56	48	51	52	61	51	65	60
30	18	14	14	17	14	10	4	5	6	7	5	11	10
												TOTAL:	599

* Based on Volume IV. SM's are included in this summary, except for SM's BC-01, RT8B-03 and RT05-11. (See note on Table 12).

total acid load in the Basin. Clean-up of a little over one-third of the mine drainage sources will reduce mine pollution in the Basin to a very significant extent, from a practical point of view.

A similar analysis by subbasin has been performed and the results are presented in Table 14. Review of these data will present a picture of the impact of a clean-up program on each subbasin. Such a program would clearly have the greatest effectiveness in subbasins such as numbers 13, 14, 15 and 26. The impact of cleaning up these subbasins on the whole Monongahela River Basin, however, may not be significant since these particular subbasins rank relatively low in the complete ranking.

Individual mines which should have first priority in a clean-up program, in each subbasin, can be extracted from Volume IV.

The data presented in this report, therefore, can be used to completely describe and design a priority scheme for a potential acid mine drainage water pollution control program by:

a) individual mines within each subbasin,

b) individual subbasins within the Monongahela River Basin, and,

c) the Monongahela River Basin as compared to other river basins in the Nation (provided similar analyses are performed for other river basins).

TABLE 14

PERCENT OF MINES IN EACH SUBBASIN AND PERCENT OF THE TOTAL ACID LOAD

Data for 100 lb/day Acid Load		Sub-Basin Rank	Sub-Basin Code	Sub-Basin Name
% Acid Load	% Mines			
99.3	50.7	1	24	Sewickley Creek
99.7	35.8	2	2	Redstone and Dunlap Creeks
95.8	60.9	3	6	Upper Monongahela River from Thurmont, West Virginia to Point Marion, Pennsylvania
97.8	63.4	4	5	Dunkard Creek
98.6	55.6	5	4	Middle Monongahela River
83.0	37.1	6	23	Lower Youghiogheny River to West-Moreland, Fayette County Line
93.8	35.4	7	8	Lower West Fork River from Clarksburg to Fairmont
92.8	39.2	8	1	Lower Monongahela River, both east and west
97.7	44.3	9	18	Lower Cheat River
97.6	24.0	10	26	Mounts Creek and Indian Creek
94.7	40.0	11	29	Castleman River
93.9	57.2	12	16	Upper Tygart Valley River above Bellington
92.1	17.4	13	11	Upper West Fork River, Clarksburg
98.7	30.4	14	3	10 Mile Creek, Pennsylvania
96.2	27.2	15	30	Upper Youghiogheny River above Confluence, Pennsylvania

TABLE 14 (Continued)

Data for 100 lb/day Acid Load		Sub-Basin Rank	Sub-Basin Code	Sub-Basin Name
% Acid Load	% Mines			
%				
90.2	33.4	16	9	10 Mile Creek and Little 10 Mile Creek in West Virginia
93.7	32.2	17	22	Black Fork south drainage
96.7	9.1	18	15	Middle Fork River
89.3	34.6	19	25	Middle Youghiogheny River from Westmoreland, Fayette County Line to Connelsville, Pennsylvania
90.2	24.0	20	13	Middle Tygart Valley River from Tygart Lake to Bellington
72.2	25.0	21	27	Youghiogheny River West from Connelsville to Confluence, Pennsylvania
92.4	33.3	22	10	Elk Creek
71.8	27.8	23	12	Lower Tygart Valley River from Thurmont to Tygart Lake
44.8	3.2	24	14	Buckhannon River
63.9	20.0	25	20	Upper Cheat River from Albright to Parsons
--	--	*	19	Big Sandy Creek
--	--	*	28	Laurel Hill Creek
--	--	*	7	Buffalo Creek and Paw Paw Creek
--	--	*	17	Leading Creek
--	--	*	21	Shavers Fork

* No sources $\geq$ 100 lbs/day

Tables III-1 through III-25 of Appendix III of this volume present data that rank AMDC sources by their average annual acidity load (lbs/day) within subbasins. These tables are similar to those presented in Volume IV except that only sources having annual average acidity loads greater than 100 lbs/day are included in the data base. The individual source as well as cumulative loads by subbasin are shown. Subbasins 19 and 28 had no openings with average annual acidity loads greater than 100 lbs/day, and subbasins 7, 17 and 21 again fell below the low cutoff point.

The cumulative loads by subbasin shown in the Tables of Appendix III are comparable to the figures in the Average Annual Acid Load Column of Table 11 except that only mines having average loads greater than 100 lbs/day enter into the figures shown in Appendix III. Also, the values for annual average acidity load presented in Tables 11 and 12 were obtained by totalling monthly acidity load values and then dividing by 12 (to get the annual average). The values presented for average annual acidity load in Appendix III were obtained by totalling the monthly average for each mine and dividing by 12 to get the annual average. Differences, therefore, will be found between these annual average values.

Of interest is the consistency of the month-to-month ranking of subbasins by load. Table 15 compares the ranking by acid load of the subbasins for January (a high load month), August (a low load month) and the average load over all months. It follows from Table 15

TABLE 15

SUBBASIN RANKING BY ACIDITY LOAD

Rank	January Acidity Load	August Acidity Load	Average Acidity Load Over All Months
1	24	24	24
2	6	6	2
3	5	2	6
4	4	5	5
5	2	4	4
6	23	23	23
7	8	8	8
8	1	26	1
9	29	1	18
10	18	29	26
11	26	18	29
12	16	3	16
13	11	16	11
14	30	11	3
15	3	30	30
16	9	9	9
17	25	22	22
18	22	15	15
19	13	25	25
20	15	13	13
21	27	27	27
22	14	12	10
23	19	14	12
24	10	10	14
25	12	19	19
26	20	20	20
27	28	28	28
28	--	--	--
29	--	--	--
30	--	--	--

that the ranking correlation between subbasins is very high across cyclical months for acid load. This pattern is typical of that found for all pollutants. It is rare to find a subbasin shift its relative load ranking by more than one decile throughout the course of a cyclical year regardless of the pollutant chosen. This strongly suggests that the month-to-month rankings between pollutants and subbasins are also very stable. Inspection of Volume IV reveals that such is the case.

Table 16 compares the ranking order of subbasins by the number of contributing sources when sources with less than 100 lbs/day are included and excluded. Table 17 compares the ranking order of subbasins by acid load when sources with less than 100 lbs/day are included and excluded. The fact that the comparative ranking of subbasins by number of sources (Table 16) scrambles a good bit more than does the ranking by load (Table 17) indicates that although the subbasins themselves differ considerably as to number of sources contributing less than 100 lbs/day of acid load, these small sources do not significantly affect the comparative total loads for the subbasins in which they are located.

TABLE 16

SUBBASIN RANKING BY NUMBER OF SOURCES

	Subbasins	
Rank	1 lbs/day	100 lbs/day
1	8	8
2	1	4
3	23	1
4	4	23
5	29	29
6	11	24
7	24	6
8	9	9
9	14	5
10	18	18
11	6	11
12	26	22
13	30	25
14	15	30
15	22	16
16	5	26
17	25	3
18	13	13
19	3	27
20	27	2
21	12	12
22	16	14
23	2	15
24	19	10
25	28	20
26	20	--
27	10	--
28	--	--
29	--	--
30	--	--

TABLE 17

SUBBASIN RANKING BY AVERAGE ANNUAL ACIDITY LOAD

Rank	Subbasins	
	1 lb/day	100 lbs/day
1	24	24
2	2	2
3	6	6
4	5	5
5	4	4
6	23	23
7	8	8
8	1	1
9	18	18
10	26	26
11	29	29
12	16	16
13	11	11
14	3	3
15	30	30
16	9	9
17	22	22
18	15	15
19	25	25
20	13	13
21	27	27
22	10	10
23	12	12
24	14	14
25	19	20
26	20	--
27	28	--
28	--	--
29	--	--
30	--	--

The month-to-month predictability of comparative loads between subbasins, taken in conjunction with the already demonstrated stable relationship between pollutants from one source, would appear to strengthen the possibility of establishing stable long term relationships between pollutants, sources and subbasins. This gives rise to the possibility of being able to predict a wide range of pollution behavior using a small amount of actual sample data.

Table 18 summarizes the data pertaining to standard mines used in this study. Appendix I contains a listing of the standard mines and the detailed information relating to exact location of the SM's available at the time of performing this effort.

TABLE 18

SUMMARY OF STANDARD MINES ACIDITY LOADS

Mine	Subbasin	Annual Average Acidity Load lb/day
GT06-01	#16, Upper Tygart Valley River	13,339
RT06-23	"	1,226
GT01-03	"	1,225
RT06-05	"	1,189
RT06-09	"	1,120
RT06-12	"	624
RT8B-03	"	12
RT09-11	"	77
Piper	#23, Lower Youghiogheny	130
Sagamore	"	125
Oneida	"	119
Florence I	# 25, Middle Youghiogheny	155
Florence II	"	212
BC-01	Not in the Monongahela Basin. Located near Moconaqua, Penna. in the anthracite region.	--

Summary of Results

The month-to-month variability of pollutant concentration for a given source tends to be small while that of flow is marked. The variability of flow is the dominant factor in determining the variability of load. The combination of: a) flow being a common denominator in calculating load for all pollutants within one source, and b) the stable behavior of concentration profiles, gives rise to the possibility of being able to predict pollutant loads using only flow information, given a good knowledge of the levels of concentration. Further if the flows of the different AMDC sources located within a particular geographical area can be related to each other and to commonly observed and measured natural phenomena (e.g., rainfall), then the problem of predicting AMDC load may be even further simplified.

The pollution load patterns of the NSS exhibited the same characteristics as did the SM's. To a large extent this was to be expected because of the manner in which the NSS time-load profiles were synthesized. However, it should be remembered that different SM time-load vectors might form the basis for the time-load profiles of different pollutants within one NSS (see Chapter III). The fact that the time-load profiles of the NSS still follow the pollutant load ranking patterns of the SM's lends additional credence to the synthesizing technique employed.

The pollutant loads observed in the various Monongahela subbasins are generally dominated by relatively few large sources in each subbasin. Less than 37 percent of the active sources in the Monongahela Basin contribute about 98 percent of AMDC load.

The data and results presented in this report could be used to design a priority format for an acid mine drainage water pollution control program on the basis of:

a) individual mines,

b) individual subbasins within the Monongahela Basin, and,

c) the Monongahela Basin compared to other basins in the U.S.

CHAPTER V

DISCUSSION

Description of Subbasins

Appendix II of this volume contains the list of subbasins and their code numbers. The mine identification numbers presented in Appendix II were used throughout this report, particularly in computerizing the available data. All of the subbasins within the Monongahela River Basin have been described during the performance of other work outside the scope of this contract. Individual subbasin maps and a composite map with all of the subbasins depicted are available at the Appalachian Regional Commission.

Available Data

A considerable amount of difficulty was experienced in amassing the data which was used for the analyses presented in this report, even with the STORET system operated by the Environmental Protection Agency and the previous work which had been done by various contractors to the EPA and the ARC in putting the data on magnetic tapes. When the data tapes were secured, additional difficulty was experienced in obtaining formats to read the information stored on the magnetic tapes and in sorting the data out. All of the data for Non-Standard Sources was obtained finally on a single magnetic tape from West Virginia

University. Dr. Charles R. Jenkins of the staff of the University was very helpful in assisting to unscramble the read format for this tape.

Data for the numbered Standard Mine sources, e.g., BC-01, were obtained from the National Environmental Research Center of EPA in Cincinnati, Ohio. Mr. Ronald Hill was very helpful in providing these data on computer cards, and the read format information.

A summary of the available information for mine drainage openings which were reviewed and utilized in this study is presented in Table 19. As closely as can be determined at this time, there are 7,008 sources and/or potential sources of mine drainage within the Monongahela River Basin distributed between West Virginia, Maryland, and Pennsylvania as shown in the Table. The data and information regarding the 7,008 sources was previously reviewed by West Virginia University under a separate contractual effort and 4,710 of the sources were eliminated from the final data compilation because they were apparently dry, based on field observations. The data for all sources was collected, over the course of several years time, by field teams of the former Federal Water Pollution Administration (which became the Federal Water Quality Administration, and finally the Environmental Protection Agency) operating in the Monongahela River Basin out of a number of field stations including Wheeling, West Virginia. This area is now encompassed by Region 3 of the Environmental Protection Agency with headquarters in Philadelphia, Pennsylvania.

TABLE 19

SUMMARY OF MINE OPENINGS REVIEWED FOR THIS STUDY

Comment	No. of Openings
Pennsylvania	2,414
Maryland	149
West Virginia	4,446
Subtotal	7,008
Reviewed by West Virginia University and eliminated because dry	- 4,710
Subtotal	2,298
Processed in this study by the computerized routines (some of these are dry also)	2,298
Number remaining after applying 1 lb/day acidity cut-off No. ≥ 1 lb/day (all included in Volume IV)	1,650
Number remaining after applying 100 lb/day acidity cutoff No. ≥ 100 lb/day (all included in Appendix III)	613*

* 599 appears as the total in Table 13 because of the averaging technique used.

The elimination of the 4,710 "dry" sources was not reviewed within the scope of work of this contract.

There remained a total therefore of 2,298 "active" sources within the Monongahela River Basin, and these were used in comparisons with the Standard Mines to generate, or synthesize, the time load profiles discussed in this report. In many instances, data collected by the field teams for these 2,298 sources did not include flow information, although chemical analyses were performed either in the field or at the laboratory after samples were collected. In those cases where no flow values were available, the remaining chemical data were not used in the time-load synthesizing process, since load values could not be calculated.

After applying a 1 lb/day acidity load cut-off value to all of the 2,298 sources, 1,650 sources remained. These sources are all presented in Volume IV of this report.

The handling of the data can be made more manageable for subsequent hand calculations by applying a 100 lb/day acidity load cut-off value to the remaining 1,650 sources. After applying this value, the number of sources contributing 100 lb/day or more to the total acidity load in the Monongahela River Basin is reduced to 613. The value of 100 lb/day was arbitrarily chosen (to correspond with ongoing and subsequent work being performed by Gibbs and Hill, Engineers, in New York City, after discussions with Mr. Joe Turcotte of that firm).

As can be seen from the results of the study, the value of 100 lbs/day is a convenient one and those sources within the category of 100 lbs/day or more of acidity load certainly constitutes the most significant fraction of all sources contributing to the acidity load. A higher value than 1 lb/day was also felt to be convenient since many of the calculations which will be performed within the scope of subsequent work being conducted by the Appalachian Regional Commission will require manual manipulation of the data.

It is felt that the data used to construct the techniques presented in this report was of the widest possible available base at the time the study was conducted.

Standard Mine Data

A complete review of the available mine drainage data was made at the facilities of the Bituminous Coal Research Library in Pittsburgh, Pennsylvania and other technical literature sources. The selection of the Standard Mines was based largely on the availability of data and information related to the particular mine discharge. Also, an attempt was made to use an array of Standard Mines representing the widest possible range of flow and load concentrations (see Figure 18) in order that any data available for Non-Standard Sources would fall within the selected range. All of the Standard Mines, except for the numbered mines largely associated with the Elkins, West Virginia mine drainage demonstration program of the EPA, were selected from one source, namely Braley's work for the Mellon Institute of February, 1962 (1).

These mines include Florence I, Florence II, Piper, Sagamore and Oneida. Data other than pH, acidity, iron and flow, were not available for these five Standard Mines.

As has been mentioned, data on manganese was practically non-existent and although some of the Non-Standard Source data did include alkalinity, it was felt that a significant amount of alkalinity information did not exist for any source which might be classified as a Standard Mine to warrant its use in synthesizing time-load profiles for alkalinity. No alkalinity or manganese profiles have been developed during the course of this work.

The locations of the numbered Standard Mines, except for BC-01, (all located within the confines of the Elkins project) were obtained with the cooperation of the staff of the Mine Drainage Program of the EPA. Detailed maps of the Elkins project are available at the National Environmental Research Center at Cincinnati, Ohio. All of the location information has been assembled in Appendix I to this volume.

Volumes II, III and IV of this report

Descriptive write-ups of each of the three volumes which accompany this volume and make up the final report of this effort, are included as Appendix IV to this volume. The significance of these volumes is apparent upon consideration of the much more detailed effort which must be performed by the Appalachian Regional Commission, subsequent to this contractual effort.

Complete descriptions of the data format are provided for both Volumes II and III. All of the raw data available for the Standard Mines is now collected together under one cover and presented as Volume II. Volume III contains all of the raw data for the 2,298 Non-Standard Sources in the Monongahela River Basin, including those "zero flow" sources.

The same descriptive material presented in Appendix IV is attached to each of the Volumes II, III and IV of this report, as preambles. The remainder of these additional volumes is entirely computer printout. All of the descriptive information, discussion, results, and summaries of results are included in Volume I.

Analytical Procedures

The mathematical procedure described in Chapter III is unique in its capability for handling large quantities of data of the kinds associated with acid mine drainage. The functional relationships described are not explicit mathematical statements. Rather, the technique is a numerical methods analysis utilizing ratios of known values. The modelling technique is relatively straightforward and does not require complicated programming procedures.

The model first, permits the selection of a time-load profile vector which describes the shape of the load curve. In order to do this, a selection of a number of mines (called Standard Mines) was made whose discharges were thought to be characteristic of many discharges located in the Monongahela River Basin. Except for standard mine BC-01, all Standard Mines were located within the Basin.

The AMDC load performance was then characterized by accumulating all of the data for that source within the typical months of the year and averaging the data to obtain a single data point. This value represented an estimate of mean concentration and mean load for each pollutant and Standard Mine, for each cyclical month. By using the ratios of one month's data to the previous month's data successively, the program generates a time-load profile.

The program then compares NSS data to the data existing for SM's by comparing ratios of characteristically available data. Operationally, given a number of points for a given NSS, the program would perform a search for the shape of an SM curve that was closest to the available data given, or do a "shape" analysis. More than 95 percent of the available NSS had only one available non-zero data point.

Having selected the "shape" which is most closely characteristic of the given NSS data, the program then slides the selected curve up and down in order to fix the magnitude of the time-load profile. The program, therefore, would very nicely have been able to handle large quantities of data for both SM's and NSS. Since, however, most NSS were represented by only one data point, the program most often selected SM's which were closest to the absolute value of the available data points.

It has already been explained that most of the NSS possessed load values which were relatively small in magnitude, and it is therefore not surprising that Standard Mine RT8B-03 was chosen most often by the program to represent NSS. The number of times each SM was chosen by the program to represent NSS is summarized in Table 20. Standard Mine RT8B-03 possessed a characteristically low time-load profile curve. The second most popular SM chosen was RT09-11. The mine chosen least often was Florence I. It is interesting to note that Standard Mine BC-01, which is a discharge from a deep anthracite mine located near Mocanaqua, Pennsylvania, not within the Monongahela Basin, ranked 6th in the number of times it was chosen to represent NSS, among all the Standard Mines. In reviewing Table 20, it should be kept in mind that data for pollutants other than acidity and iron were not available for the named mines. Therefore, it was not possible for the program to make selections of the SM's in the categories of sulfate, hardness or aluminum.

It is important to recognize that most numerical fitting techniques require that the functional form of a relationship be known. In this case, the functional form was not known and attempts were not made to develop one because of the observed erratic nature of the available data and the sparcity of the data. In this case, the ratio technique and the use of the time-load vector of one of the SM's to represent the data from the NSS, represents a valuable tool for analysis of data of this kind.

TABLE 20

NUMBER OF TIMES A GIVEN SM WAS CHOSEN

TO REPRESENT AN NSS, BY POLLUTANT

No. of NSS 002298
No. of ALK 000752

SM	ACID	IRON	SULF.	HARD.	ALK	AL	TOTAL
BC-01	63	55	65	75			258
FLOR-1	48						48
FLOR-2	85						85
GTOI-03	19	23	52	76		53	223
GTOE-01	10	19	37	33		31	130
ONEIDA	55						55
PIPER	139						139
RTO6-05	50	96	67	71		51	335
RTO6-09	30	44	31	108		14	227
RTO6-12	46	37	151	172		94	500
RTO6-23	45	41	60	85		57	288
RTO9-11	134	302	317	683		347	1,783
RT88-03	1,228	1,560	1,495	972		1,443	6,698
SAGAMORE	81						81

The observation that the concentration profile remains relatively constant (or that mines are represented by relatively flat concentration/time curves when compared to flow) is not a unique observation. This has been shown to be the case in other mine drainage studies and in salinity investigations in some of the western U.S. river basins.

Another important observation with regard to the data is that it would appear that mines can be represented by a relationship of ranking between various pollutants which remains relatively stable. For example, if iron is generally higher than sulfate during one month, that will generally be the case for the period of the whole cyclical year. It might be possible, on this basis, to identify mines by the ranking order of the measured pollutants associated with the discharge.

An important aspect of the modelling and analysis procedure was that the program was designed to be free to pick different SM's to represent NSS for each of the pollutants, e.g., iron from BC-01, sulfate from RT06-23, etc. This did, in fact, happen relatively often during the analysis. A significant fraction of the time, however, the model did select one SM to represent all of the pollutant time-load vectors. The question of whether the numerical ratios of one pollutant to another, for example, iron to aluminum, will remain consistently the same over extended periods of observation, could very well be the subject of further research.

It should be emphasized that the verification of the modelling technique described in this report has not been completely performed. The success of the technique up to the present time would appear to indicate that it would be highly desirable to perform similar analyses with regard to the pollutant concentration and flow relationships in streams. These data are available in the STORET system.

Following such an analysis, it would be possible to relate the time-load relationships described in this report for all sources within a subbasin to the time-load relationship derived on the basis of stream data. This analysis could substantially verify the technique developed and described herein. The analysis would require a considerable amount of work associated with geographically locating all of the NSS.

The analysis of the data also suggests that given a very wide base of SM sources (much greater than the 14 used here), the pollutant time-load vectors will fall into identifiable families of curves. This suggests the possibility that continued research might well indicate that analysis of only one or two important parameters of a mine discharge, for example, flow and acidity, could be used to project the whole range of pollutant time-load vectors. The pollution load of a mine discharge could subsequently be described within confidence limits which would be tolerable for planning purposes and the preparation of preliminary designs.

Finally, review of the data resulting from the use of the modelling technique suggests that the degree of variability and unpredictability previously associated with acid mine drainage discharges, may in fact be less variable and more predictable than has been felt in the past. In any case, it would appear to be worthwhile to pursue a program directed at discovering and defining explicit mathematical relationships for describing mine drainage discharges. Assuming such relationships could be found, they would become extremely important to designers of water quality control programs, treatment facilities, as well as to planning and budget agencies.

Other Notes

On page 7 of the summary report entitled, "Monongahela River Mine Drainage Remedial Project", published by EPA in 1971, it is stated, "... of the 7,002 mines and mine-associated sites, 3,046 were draining at the time of the inventory". These numbers to not compare exactly with the numbers reported herein. A total of 2,298 non-zero flow discharges were available for analysis during this study. A general conclusion reached in the summary report was that a relatively small number of sources in an area contributed most of the pollution load. This observation does compare to the results presented herein.

It should be kept in mind that although some of the sites were not draining at the time of field inventory by project staff in the Monongahela River Basin, during periods of rainfall these "zero flow" discharge points can and probably do contribute to the total mine drainage pollution load over the course of the year. On this basis

estimates of total load arrived at in this report and discussed in Chapter IV are likely to be low.

In this regard, it is interesting to compare the values given in this report to some of the references which reviewed the old Federal Mine Sealing projects. Fellows (3) reports that as a result of a survey of data obtained during investigations prior to 1937, that the following may be estimated sulfuric acid drainage loads from abandoned mines along tributaries of the Ohio River:

State	Drainage of Sulfuric Acid (lbs/day)
Pennsylvania	5,000,000
West Virginia	1,877,300
Ohio	2,700,000
Kentucky	2,848,545

These figures would, of course, include drainage not only from the Monongahela but from the Allegheny and other tributaries to the Ohio River in Kentucky and Ohio.

The Ohio River Pollution Survey (4) in 1942 reported:

	Original	Present Load After Mine Sealing	Complete Program After Mine Sealing
Monongahela (Except Youghiogheny)	3,841,000	2,461,000	1,827,000
Youghiogheny	1,204,000	1,079,000	624,000
Total	5,045,000	3,540,000	2,451,000

All values are in pounds per day of mine acid loads as calcium carbonate. It was estimated then that 2,451,000 pounds per day of acidity would still be produced in the whole Monongahela River Basin after the completion of the mine sealing programs. The estimate of total load arrived at in Chapter IV is about 50 percent of these estimates.

Much more data has been collected since 1942 and recent estimates are likely to be more accurate. Some control programs have also been implemented in the Monongahela Basin since 1942 and this would result in lower total loads today as well.

Without presenting a definite ranking, the Monongahela Summary Report (2) presented seven Monongahela subbasins as being the greatest contributors to the total pollution load in the basin in the order given below. The top seven subbasin rankings derived and presented in this report are given for comparison:

	Ranking in This Report	Monongahela Summary Report
1.	Sewickley Creek	Middle Monongahela Basin
2.	Redstone & Dunlap Creeks	Upper Monongahela Subbasin
3.	Upper Monongahela Basin	Lower West Fork River
4.	Dunkard Creek	Lower Tygart Subbasin
5.	Middle Monongahela	Lower Cheat River
6.	Lower Youghiogheny	Lower Youghiogheny
7.	Lower West Fork River	Sewickley Creek

The two subbasins not present in the top seven ranking order of this report are the Lower Tygart and Lower Cheat subbasins.

Although the number of draining sites does not correspond with the data presented herein, the total net acidity load in pounds per day in the Monongahela Basin presented in the EPA Monongahela Summary report is 1,079,575 pounds per day. This compares favorably with the 1,156,000 pounds per day presented in Chapter IV.

Figure 19 illustrates the primary streams in the Monongahela River Basin.

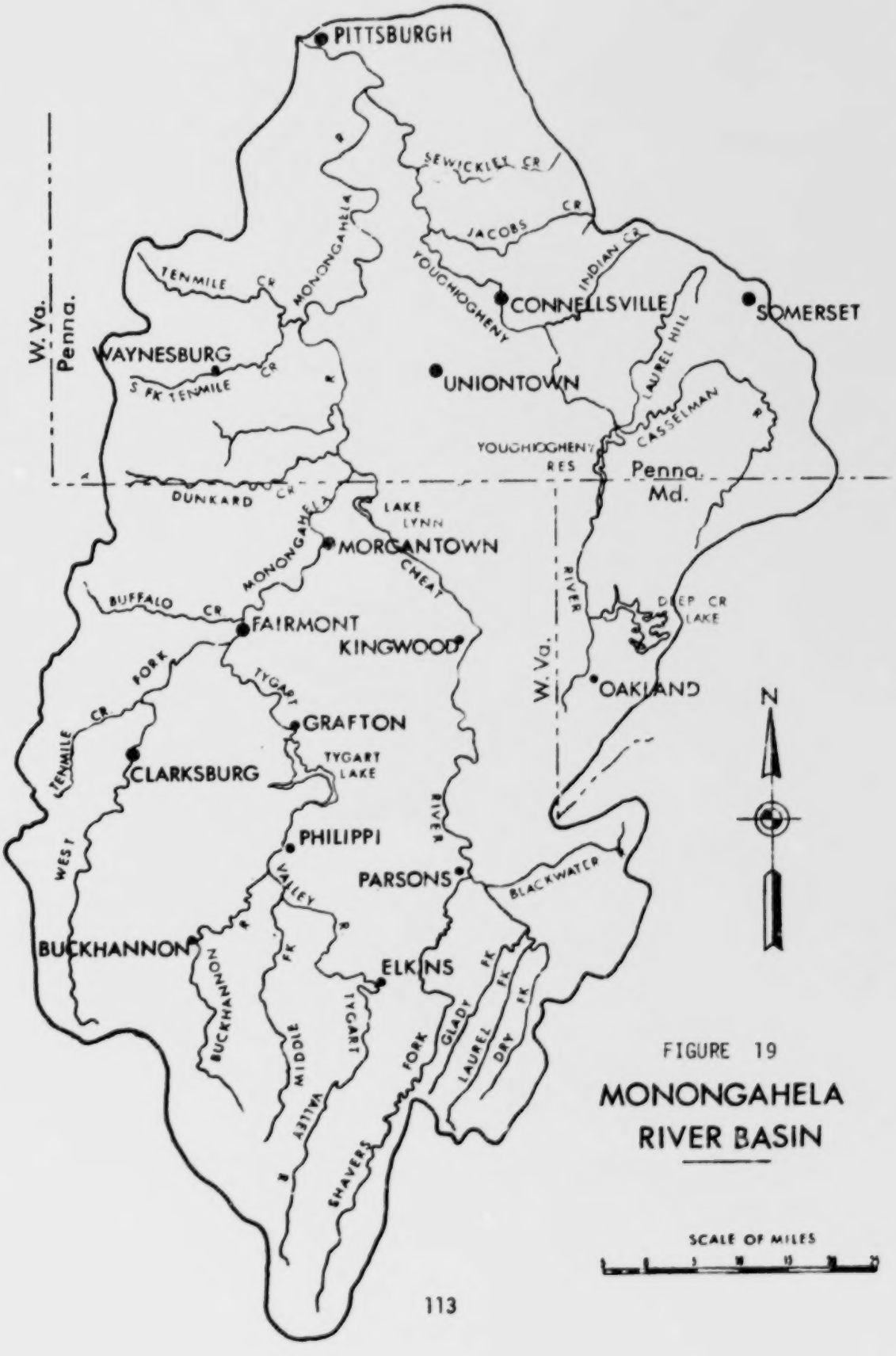


FIGURE 19

MONONGAHELA RIVER BASIN

CHAPTER VI

REFERENCES

1. Braley, S. A., "Special Report on an Evaluation of Mine Sealing", Coal Industry Advisory Committee to the Ohio River Valley Water Sanitation Commission, Mellon Institute, Research Project No. 370-8, February 1962.

2. Summary Report, Monongahela River Mine Drainage Remedial Project, Report of the Technical Committee to the Enforcement Conference on the Monongahela River and Its Tributaries, Environmental Protection Agency, Division of Field Investigations, NERC, Cincinnati, Ohio, 1971.

3. Fellows, Perry A., "Sealing Projects Sharply Reduce Stream Pollution from Abandoned Mines", Coal Age, 42, 4, pp. 158-161, April, 1937.

4. Ohio River Pollution Survey, Final Report to the Ohio River Committee, Supplement C, Acid Mine Drainage Studies, USPHS, Cincinnati, Ohio, 1942.

APPENDIX I

LISTING AND DESCRIPTION OF STANDARD MINES (SM)

NOTE: All of the numbered discharges appearing in this Appendix were located on the so-called "Elkins" Acid Mine Drainage Control Project near Elkins and Coalton, West Virginia. A detailed set of maps is available for this project but these maps are not available on a wide-spread basis. Copies of the maps can be seen at the National Environmental Research Center, Environmental Protection Agency, Cincinnati, Ohio in the Acid Mine Drainage Control Section. As such, latitude and longitude are given where known and also, for purposes of completeness, the location and map numbers taken during the project are given. For purposes of reference, therefore, the reader has available in this Appendix, all available location information.

PIPER MINE

The Piper Mine is located on Indian Creek, which is a tributary to the Youghiogheny River in the Monongahela River Basin. The discharge from the Piper Mine enters Indian Creek. The mine is in a wooded area with a maximum cover of about 50 feet. The cover is dense rock with very little topsoil. The mine has previously been sealed under the Federal Mine Sealing Program and the roof is fractured although no sink holes are apparently present.

SAGAMORE AND ONEIDA MINES

These mines also discharge into Indian Creek between Jones' Mills and Indian Head. The openings are only a short distance from the stream. These mines had also been sealed under the Federal Mine Sealing Program but the seals have badly deteriorated. The Oneida mine is characterized by a large volume of discharge.

FLORENCE I and II

The Florence mines are located on opposite sides of an unnamed tributary to Jacob's Creek near Scottdale, Pennsylvania. Jacob's

Creek is also a tributary to the Youghiogheny and lies within the Monongahela River Basin. The mines have never been sealed and are characterized by about 200 feet of cover.

BC-01

Standard mine BC-01 is deep mine drainage from an anthracite mine near Moconaqua, Pennsylvania. This mine is not in the Monongahela River watershed.

GT01-03

This is a deep mine discharge near Elkins, West Virginia located at:

Latitude	38° 55' 20" N
Longitude	79° 52' 42" W

GT06-01

This is the largest deep mine discharge on the Elkins project. It is located at:

Latitude	38° 55' 13" N
Longitude	79° 51' 40" W

RT06-05

Standard mine RT06-05 is located at:

Latitude	38° 53' 41" N
Longitude	79° 58' 39" W

This discharge contains deep mine water and discharges into Kittle Run at the Kittle Run swamp, approximately 200 yards below the sampling station RT6-20. EPA location numbers are N691,430 and E2,291,300 and the mine

is shown on map 4C.

RT06-09

This mine is located at:

Latitude	38° 53' 38" N
Longitude	79° 59' 02" W

This mine is located in the western-most part of work area 10 (EPA Elkins project) and the EPA identification numbers are N690,930 and E2,288,690 and located on map 4C. The discharge contained only deep mine discharges and drained into Kittle Run approximately 500 feet above station RT6-21.

RT06-12

This mine is located at:

Latitude	38° 53' 30" N
Longitude	79° 58' 49" W

The mine is located in EPA work area 15 of what is called Sugar Tree Turn. EPA I.D. numbers are N690,150 and E2,289,180 on map 4C. It contains deep mine discharge and surface water but mostly deep mine discharge. It drains into Kittle Run at Kittle Run swamp. Water drains from Flatbush work areas 5, 6, 7 and possibly area 29 through the mine.

RT06-23

This mine is located at:

Latitude	38° 53' 54" N
Longitude	79" 59' 31" W

The discharge contains deep mine drainage with some strip runoff. Most of the drainage comes out of the old drift mine opening called "26-Right". The EPA I.D. numbers are N692,850 and E2,286,710 and are located on map 4C. Most of the discharge water runs into a deep mine just above an air shaft approximately in the center of area 10. This site represents discharge from 26-Right and Flatbush area near the old Sianato mine.

RT09-11

This mine is located at:

Latitude	38° 53' 28" N
Longitude	80° 00' 20" W

The drainage is from a mine opening in a strip mine located in area 24. The strip has been backfilled. The EPA I.D. numbers are N690,305 and E2,283,280 and located on map 4C. This drainage contains only the deep mine discharge, which drains into a tributary of Flatbush 2050 feet from its mouth.

RT8B-03

This mine is located at:

Latitude	38° 52' 56" N
Longitude	79° 58' 00" W

The discharge is located northeast of Mabie and southeast of area 44. The EPA I.D. numbers are N686,750 and E2,291,500 and located on map 7C. The drainage is from a deep mine in work area 11. The drainage is into Roaring Creek.

APPENDIX II

MONONGAHELA RIVER SUBBASIN CODE

1. Lower Monongahela River, both east and west

   Peters Creek
   Pikes Creek
   Pigeon Creek

2. Redstone and Dunlap Creeks

3. 10 Mile Creek, Pennsylvania, including

   South Fork

4. Middle Monongahela River, including

   Georges Creek
   Whiteley Creek and,
   east and west Monongahela drainage to Brownsville

5. Dunkard Creek

6. Upper Monongahela River from Thurmont, West Virginia to Point Marion, Pennsylvania, including

   Deckers Creek and,
   both east and west drainage (excluding portion covered by Buffalo Creek and Paw Paw Creek drainage area)

7. Buffalo Creek and Paw Paw Creek, including

   west drainage, Monongahela River

8. Lower West Fork River from Clarksburg to Fairmont,

   east and west drainages excepting 10 Mile Creek area

9. 10 Mile Creek and Little 10 Mile Creek in West Virginia

10. Elk Creek

11. Upper West Fork River, Clarksburg

APPENDIX II (Continued)

12. Lower Tygart Valley River from Thurmont to Tygart Lake

13. Middle Tygart Valley River from Tygart Lake to Bellington

14. Buckhannon River

15. Middle Fork River

16. Upper Tygart Valley River above Bellington, excluding

    Leading Creek

17. Leading Creek

18. Lower Cheat River, excluding

    Big Sandy Creek
    the Lower Cheat from the mouth of the river to Albright

19. Big Sandy Creek

20. Upper Cheat River from Albright to Parsons, including

    north drainage of Black Fork

21. Shavers Fork

22. Black Fork south drainage, including

    Otter Creek
    Dry Fork
    Glady Fork
    Laurel Fork
    Red Creek
    Black Water River

23. Lower Youghiogheny River to Westmoreland, Fayette County Line, including

    Turtle Creek

24. Sewickley Creek

25. Middle Youghiogheny River from Westmoreland, Fayette County Line to Connelsville, Pennsylvania, including

    Jacob's Creek

APPENDIX II (Continued)

26. Mounts Creek and Indian Creek, including minor east Youghiogheny River drainage

27. Youghiogheny River West from Connelsville to Confluence, Pennsylvania

28. Laurel Hill Creek

29. Castleman River

30. Upper Youghiogheny River above Confluence, Pennsylvania

APPENDIX III

RANKING OF MINES BY SUBBASINS*

* Mines contributing $\geq$ 100 lb/day acidity load

APPENDIX III

TABLE III-1

SUB-BASIN ACIDITY LOADING

Basin No. 01 - Lower Monongahela River, both east and west
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	250211	4,243	4,243	10.27
2	250101	3,349	7,592	8.11
3	120051	2,909	10,501	7.04
4	250161	2,019	12,520	4.89
5	250232	1,629	14,149	3.94
6	040151	1,442	15,591	3.49
7	250931	1,423	17,014	3.44
8	170151	1,329	18,343	3.22
9	151261	1,328	19,671	3.21
10	251001	1,293	20,964	3.13
11	150571	1,225	22,189	2.97
12	250443	1,213	23,402	2.94
13	130161	1,206	24,608	2.92
14	251292	1,186	25,794	2.87
15	250242	1,179	26,973	2.85
16	120053	1,142	28,115	2.76
17	251221	1,135	29,250	2.75
18	250132	1,093	30,343	2.65
19	250781	1,019	31,362	2.47
20	250191	677	32,039	1.64
21	250171	668	32,707	1.62
22	050241	617	33,324	1.49
23	250102	559	33,883	1.35
24	250441	515	34,398	1.25
25	050091	342	34,740	0.83
26	050293	331	35,071	0.80
27	110182	330	35,401	0.80
28	040081	296	35,697	0.72
29	250941	260	35,957	0.63
30	130091	211	36,168	0.51
31	130172	211	36,379	0.51
32	130111	200	36,579	0.48
33	130201	190	36,769	0.46
34	051421	178	36,947	0.43
35	170171	158	37,105	0.38

APPENDIX III

TABLE III-1 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 01 - Lower Monongahela River, both east and west
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
36	250153	156	37,261	0.38
37	170211	155	37,416	0.38
38	150601	152	37,568	0.37
39	130081	152	37,720	0.37
40	250152	148	37,868	0.36
41	150191	147	38,015	0.36
42	250141	142	38,157	0.34
43	251321	141	38,298	0.34
44	150611	134	38,432	0.32
45	170111	132	38,564	0.32
46	150871	132	38,696	0.32
47	130122	128	38,824	0.31
48	050294	126	38,950	0.31
49	151231	126	39,076	0.31
50	151101	124	39,200	0.30
51	150391	124	39,324	0.30
52	250812	121	39,445	0.29
53	151121	118	39,563	0.29
54	151271	118	39,681	0.29
55	130121	117	39,798	0.28
56	040132	113	39,911	0.27
57	150361	112	40,023	0.27
58	251162	112	40,135	0.27
59	251531	111	40,246	0.27
60	150511	111	40,397	0.27
61	251441	109	40,466	0.26
62	250591	109	40,575	0.26
63	150041	109	40,684	0.26
64	150761	108	40,792	0.26
65	150031	106	40,898	0.26
66	150291	104	41,002	0.25
67	150791	102	41,104	0.25
68	250973	102	41,206	0.25
69	150381	101	41,307	0.24

APPENDIX III

TABLE III-2

SUB-BASIN ACIDITY LOADING

Basin No. 02 - Redstone and Dunlap Creek
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	342193	41,014	41,014	29.94
2	342192	41,014	82,028	29.94
3	342191	40,196	122,224	29.34
4	342211	11,697	133,921	8.54
5	342001	3,068	136,989	2.24

APPENDIX III

TABLE III-3

SUB-BASIN ACIDITY LOADING

Basin No. 03 - 10 Mile Creek, Pennsylvania
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	120041	14,342	14,342	93.39
2	010091	211	14,553	1.37
3	210441	207	14,760	1.35
4	010094	169	14,929	1.10
5	210641	154	15,083	1.00
6	010031	153	15,236	1.00
7	010011	121	15,357	0.79

APPENDIX III

TABLE III-4

SUB-BASIN ACIDITY LOADING

Basin No. 04 - Middle Monongahela River
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	201191	31,597	31,597	31.12
2	204013	9,463	41,060	9.32
3	204131	5,272	46,332	5.19
4	201385	3,077	49,409	3.03
5	201412	2,730	52,139	2.69
6	204112	2,688	54,827	2.65
7	201401	2,333	57,160	2.30
8	201192	2,291	59,451	2.26
9	203311	2,057	61,508	2.03
10	201445	1,609	63,117	1.58
11	203804	1,593	64,710	1.57
12	201602	1,355	66,065	1.33
13	201411	1,300	67,365	1.28
14	201651	1,292	68,657	1.27
15	201603	1,277	69,934	1.26
16	203871	1,210	71,144	1.19
17	204171	1,152	72,296	1.13
18	201511	1,146	73,442	1.13
19	201491	1,106	74,548	1.09
20	203961	1,085	75,633	1.07
21	200051	1,085	76,718	1.07
22	204031	1,077	77,795	1.06
23	201461	1,020	78,815	1.00
24	201552	1,018	79,833	1.00
25	203811	1,015	80,848	1.00
26	203521	924	81,772	0.91
27	201181	920	82,692	0.91
28	200081	899	83,591	0.89
29	200041	863	84,454	0.85
30	204032	859	85,313	0.85

APPENDIX III

TABLE III-4 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 04 - Middle Monongahela River
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
31	204012	804	86,117	0.79
32	204172	726	86,843	0.72
33	204071	629	87,472	0.62
34	203981	622	88,094	0.61
35	200062	575	88,669	0.57
36	203842	533	89,202	0.52
37	204113	468	89,670	0.46
38	201642	431	90,101	0.42
39	200063	428	90,529	0.42
40	201382	424	90,953	0.42
41	201611	411	91,364	0.40
42	201441	398	91,762	0.39
43	201451	355	92,117	0.35
44	203791	352	92,469	0.35
45	204016	344	92,813	0.34
46	201371	325	93,138	0.32
47	201443	313	93,451	0.31
48	204021	306	93,757	0.30
49	204011	304	94,061	0.30
50	201501	288	94,349	0.28
51	201431	276	94,625	0.27
52	201391	267	94,892	0.26
53	204281	267	95,159	0.26
54	201383	257	95,416	0.25
55	203523	250	95,666	0.25
56	203962	247	95,913	0.24
57	201081	244	96,157	0.24
58	203624	243	96,400	0.24
59	203861	233	96,633	0.23
60	201374	225	96,858	0.22

APPENDIX III

TABLE III-4 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 04 - Middle Monongahela River
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
61	204211	208	97,066	0.20
62	203522	207	97,273	0.20
63	201331	205	97,478	0.20
64	201384	201	97,679	0.20
65	203881	196	97,875	0.19
66	204401	196	98,071	0.19
67	201541	191	98,262	0.19
68	050963	172	98,434	0.17
69	201373	161	98,595	0.16
70	201311	158	98,753	0.16
71	340081	155	98,908	0.15
72	201432	153	99,061	0.15
73	204121	149	99,210	0.15
74	201551	148	99,356	0.15
75	201243	144	99,502	0.14
76	204014	140	99,642	0.14
77	203802	139	99,781	0.14
78	204015	136	99,917	0.13
79	203803	133	100,050	0.13
80	201482	133	100,183	0.13
81	201641	132	100,315	0.13
82	203963	131	100,446	0.13
83	200661	131	100,577	0.13
84	204251	131	100,708	0.13
85	201601	128	100,836	0.13
86	204271	124	100,960	0.12
87	203901	120	101,080	0.12
88	200071	119	101,199	0.12
89	200061	117	101,316	0.12
90	201361	112	101,428	0.11
91	200042	101	101,529	0.10

APPENDIX III

TABLE III-5

SUB-BASIN ACIDITY LOADING

Basin No. 05 - Dunkard Creek
Ranking by Acidity

Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	440515	37,880	37,880	30.65
2	440514	28,057	65,937	22.70
3	440701	23,252	89,199	18.82
4	440551	16,865	106,064	13.65
5	440512	6,220	112,284	5.03
6	440513	2,026	114,310	1.64
7	200233	1,500	115,810	1.21
8	200391	1,485	117,295	1.20
9	200235	1,413	118,708	1.14
10	440552	1,138	119,846	0.92
11	200482	1,107	120,953	0.90
12	200271	800	121,753	0.65
13	200238	441	122,194	0.36
14	200272	280	122,474	0.23
15	200331	235	122,709	0.19
16	200411	193	122,902	0.16
17	200201	170	123,072	0.14
18	200481	150	123,222	0.12
19	440702	126	123,348	0.10
20	200239	121	123,469	0.10
21	200441	111	123,580	0.09

APPENDIX III

TABLE III-6

SUB-BASIN ACIDITY LOADING

Basin No. 06 - Upper Monongahela River from Thurmont, West Virginia to Point Marion, Penna.

Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	440421	39,008	39,008	28.82
2	480051	25,738	64,746	19.01
3	440423	22,035	86,781	16.28
4	440415	10,139	96,920	7.49
5	440413	9,581	106,501	7.08
6	440543	7,771	114,272	5.74
7	480741	2,246	116,518	1.66
8	461022	2,108	118,626	1.56
9	440411	1,840	120,466	1.36
10	480841	1,638	122,104	1.21
11	440422	1,467	123,571	1.08
12	480581	1,377	124,948	1.02
13	481032	1,226	126,174	0.91
14	480911	1,220	127,394	0.90
15	440417	1,185	128,579	0.88
16	440424	1,135	129,714	0.84
17	440541	1.083	130,797	0.80
18	481031	789	131,586	0.58
19	480921	709	132,295	0.52
20	481121	635	132,930	0.47
21	480583	473	133,403	0.35
22	480801	324	133,727	0.24
23	480622	294	134,021	0.22
24	481122	206	134,227	0.15
25	440442	143	134,370	0.11
26	480732	137	134,507	0.10
27	480802	132	134,639	0.10
28	481033	132	134,771	0.10
29	481214	131	134,902	0.10
30	481021	122	135,024	0.09
31	480021	121	135,145	0.09
32	480791	115	135,260	0.08
33	480611	103	135,363	0.08

APPENDIX III

TABLE III-7

SUB-BASIN ACIDITY LOADING

Basin No. 08 - Lower West Fork River from Clarksburg to Fairmont
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	541863	10,082	10,082	17.93
2	540291	3,192	13,274	5.68
3	541805	3,175	16,449	5.65
4	640956	2,166	18,615	3.85
5	541991	1,992	20,607	3.54
6	640951	1,562	22,169	2.78
7	540203	1,396	23,565	2.48
8	541864	1,348	24,913	2.40
9	541731	1,342	26,255	2.39
10	541802	1,310	27,565	2.33
11	540051	1,290	28,855	2.29
12	540171	1,273	30,128	2.26
13	542011	1,246	31,374	2.22
14	640957	1,227	32,601	2.18
15	540702	1,214	33,815	2.16
16	540841	1,166	34,981	2.07
17	541831	1,089	36,070	1.94
18	541862	1,063	37,133	1.89
19	540222	1,042	38,175	1.85
20	540431	976	39,151	1.74
21	540861	906	40,057	1.61
22	490161	872	40,929	1.55
23	640955	844	41,773	1.50
24	460102	826	42,599	1.47
25	540223	676	43,275	1.20
26	541823	592	43,867	1.05
27	540483	564	44,431	1.00
28	541291	529	44,960	0.94
29	460061	504	45,464	0.90
30	541992	482	45,946	0.86

APPENDIX III

TABLE III-7 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 08 - Lower West Fork River from Clarksburg to Fairmont
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
31	640612	443	46,389	0.79
32	540322	368	46,757	0.65
33	460661	349	47,106	0.62
34	540341	297	47,403	0.53
35	460351	295	47,698	0.52
36	540201	284	47,982	0.51
37	541841	243	48,225	0.43
38	541951	237	48,462	0.42
39	490322	236	48,698	0.42
40	540209	228	48,926	0.41
41	460103	227	49,153	0.40
42	541824	226	49,379	0.40
43	460111	222	49,601	0.39
44	460101	192	49,793	0.34
45	460261	177	49,970	0.31
46	490491	176	50,146	0.31
47	490063	172	50,318	0.31
48	461032	168	50,486	0.30
49	542001	164	50,650	0.29
50	540292	163	50,813	0.29
51	541531	162	50,975	0.29
52	540252	161	51,136	0.29
53	460281	159	51,295	0.28
54	541722	159	51,454	0.28
55	490251	156	51,610	0.28
56	490533	153	51,763	0.27
57	540302	151	51,914	0.27
58	540301	150	52,064	0.27
59	540701	145	52,209	0.26
60	540482	145	52,354	0.26

APPENDIX III

TABLE III-7 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 08 - Lower West Fork River from Clarksburg to Fairmont
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
61	541801	145	52,499	0.26
62	640611	144	52,643	0.26
63	540208	139	52,782	0.25
64	490291	138	52,920	0.25
65	490102	137	53,057	0.24
66	490314	135	53,192	0.24
67	640954	134	53,326	0.24
68	540451	134	53,460	0.24
69	540551	133	53,593	0.24
70	540471	129	53,722	0.23
71	540204	126	53,848	0.22
72	460051	126	53,974	0.22
73	490041	125	54,099	0.22
74	640441	125	54,224	0.22
75	460055	123	54,347	0.22
76	541803	122	54,469	0.22
77	540202	117	54,586	0.21
78	541721	116	54,702	0.21
79	490532	115	54,817	0.20
80	490133	115	54,932	0.20
81	540472	114	55,046	0.20
82	540652	113	55,159	0.20
83	490064	113	55,272	0.20
84	540261	113	55,385	0.20
85	490231	110	55,495	0.20
86	640581	110	55,605	0.20
87	640741	107	55,712	0.19
88	540206	107	55,819	0.19
89	460113	103	55,922	0.18
90	460114	103	56,025	0.18
91	541171	103	56,128	0.18
92	640333	101	56,229	0.18

APPENDIX III

TABLE III-8

SUB-BASIN ACIDITY LOADING

Basin No. 09 - 10 Mile Creek and Little 10 Mile Creek in West Virginia
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	610211	1,458	1,458	19.16
2	610031	1,247	2,705	16.39
3	540091	795	3,500	10.45
4	540161	458	3,958	6.02
5	540162	342	4,300	4.50
6	610191	305	4,605	4.01
7	610231	290	4,895	3.81
8	610243	278	5,173	3.65
9	540121	246	5,419	3.23
10	610181	218	5,637	2.87
11	610131	197	5,834	2.59
12	640991	160	5,994	2.10
13	540061	158	6,152	2.08
14	540062	148	6,300	1.95
15	610242	148	6,448	1.95
16	641331	148	6,596	1.95
17	640812	137	6,733	1.80
18	610162	137	6,870	1.80
19	610091	136	7,006	1.79
20	641121	127	7,133	1.67
21	641141	125	7,258	1.64
22	610252	125	7,383	1.64
23	610111	116	7,499	1.52
24	610141	109	7,608	1.43

APPENDIX III

TABLE III-9

SUB-BASIN ACIDITY LOADING

Basin No. 10 - Elk Creek
Ranking by Acidity

		Average Annual Acidity (Lbs./Day)		
Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	460552	796	796	100.00

APPENDIX III

TABLE III-10

SUB-BASIN ACIDITY LOADING

Basin No. 11 - Upper West Fork River, Clarksburg
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	620301	13,510	13,510	71.00
2	580503	1,327	14,837	6.97
3	620111	1,211	16,048	6.36
4	630481	948	16,996	4.98
5	620541	242	17,238	1.27
6	620422	223	17,461	1.17
7	620524	212	17,673	1.11
8	620375	166	17,839	0.87
9	620562	162	18,001	0.85
10	640221	149	18,150	0.78
11	620711	147	18,297	0.77
12	620583	135	18,432	0.71
13	620372	126	18,558	0.66
14	630491	124	18,682	0.65
15	630431	122	18,804	0.64
16	620072	117	18,921	0.61
17	620361	108	19,029	0.57

APPENDIX III

TABLE III-11

SUB-BASIN ACIDITY LOADING

Basin No. 12 - Tygart Valley River from Thurmont to Tygart Lake, lower
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	421893	143	143	27.82
2	421861	141	284	27.43
3	421811	122	406	23.74
4	421892	108	514	21.01

APPENDIX III

TABLE III-12

SUB-BASIN ACIDITY LOADING

Basin No. 13 - Tygart Valley River from Tygart Lake to Bealington, middle
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	460012	1,481	1,481	44.14
2	460011	1,284	2,765	38.27
3	460901	222	2,987	6.62
4	460401	135	3,122	4.02
5	460991	133	3,255	3.96
6	460941	100	3,355	2.98

APPENDIX III

TABLE III-13

SUB-BASIN ACIDITY LOADING

Basin No. 14 - Buckhannon River
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	511941	132	132	56.41
2	512111	102	234	43.59

APPENDIX III

TABLE III-14

SUB-BASIN ACIDITY LOADING

Basin No. 15 - Middle Fork River
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	510501	5,674	5,674	97.79
2	510516	128	5,802	2.21

APPENDIX III

TABLE III-15

SUB-BASIN ACIDITY LOADING

Basin No. 16 - Upper Tygart Valley River above Bealington
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	GT06-1	13,339	13,339	64.03
2	RT6-23	1,226	14,565	5.89
3	GT01-3	1,225	15,790	5.88
4	512431	1,191	16,981	5.72
5	RT06-5	1,189	18,170	5.71
6	RT06-9	1,120	19,290	5.38
7	510226	634	19,924	3.04
8	RT6-12	624	20,548	3.00
9	510221	284	20,832	1.36

APPENDIX III

TABLE III-16

SUB-BASIN ACIDITY LOADING

Basin No. 18 - Lower Cheat River
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	204391	11,452	11,452	28.74
2	590807	9,616	21,068	24.13
3	590151	6,535	27,603	16.40
4	204395	3,491	31,094	8.76
5	590301	1,470	32,564	3.69
6	204381	1,363	33,927	3.42
7	590711	1,095	35,022	2.75
8	204191	883	35,905	2.22
9	204181	786	36,691	1.97
10	590771	663	37,354	1.66
11	591061	565	37,919	1.42
12	590381	552	38,471	1.39
13	590741	256	38,727	0.64
14	204393	247	38,974	0.62
15	590382	144	39,118	0.36
16	590361	134	39,252	0.34
17	590062	126	39,378	0.32
18	204382	122	39,500	0.31
19	591091	122	39,622	0.31
20	590271	119	39,741	0.30
21	590061	106	39,847	0.27

APPENDIX III

TABLE III-17

SUB-BASIN ACIDITY LOADING

Basin No. 20 - Upper Cheat River from Albright to Parsons
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	500032	161	161	100.00

APPENDIX III

TABLE III-18

SUB-BASIN ACIDITY LOADING

Basin No. 22 - Black Fork south drainage
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	450461	4,926	4,926	67.90
2	450341	647	5,573	8.92
3	450412	408	5,981	5.62
4	450311	175	6,156	2.41
5	450421	164	6,320	2.26
6	450482	158	6,478	2.18
7	450471	158	6,636	2.18
8	450501	140	6,776	1.93
9	450401	136	6,912	1.87
10	450342	117	7,029	1.61
11	450411	114	7,143	1.57
12	450301	112	7,255	1.54

APPENDIX III

TABLE III-19

SUB-BASIN ACIDITY LOADING

Basin No. 23 - Lower Youghiogheny River to West Moreland
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	110323	25,926	25,926	35.48
2	180951	10,162	36,088	13.91
3	320281	8,905	44,993	12.19
4	110322	6,884	51,877	9.42
5	320091	1,633	53,510	2.23
6	030071	1,251	54,761	1.71
7	220991	1,211	55,972	1.66
8	260081	1,209	57,181	1.65
9	320102	1,148	58,329	1.57
10	260082	1,131	59,460	1.55
11	260061	1,065	60,525	1.46
12	320011	958	61,483	1.31
13	220701	690	62,173	0.94
14	320192	651	62,824	0.89
15	030012	649	63,473	0.89
16	260291	581	64,054	0.80
17	030221	443	64,497	0.61
18	260042	440	64,937	0.60
19	320242	419	65,356	0.57
20	220151	393	65,749	0.54
21	320196	361	66,110	0.49
22	320272	337	66,447	0.46
23	220211	323	66,770	0.44
24	260221	292	67,062	0.40
25	320231	291	67,353	0.40
26	220512	280	67,633	0.38
27	030141	280	67,913	0.38
28	030211	262	68,175	0.36
29	091711	246	68,421	0.34
30	260181	227	68,648	0.31

APPENDIX III

TABLE III-19 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 23 - Lower Youghiogheny River to West Moreland
Ranking by Acidity **Average Annual Acidity** (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
31	220561	225	68,873	0.31
32	220531	219	69,092	0.30
33	320081	213	69,305	0.29
34	220473	207	69,512	0.28
35	180731	175	69,687	0.24
36	180781	155	69,842	0.21
37	030201	153	69,995	0.21
38	180721	149	70,144	0.20
39	220511	149	70,293	0.20
40	320202	139	70,432	0.19
41	030191	138	70,570	0.19
42	030231	137	70,707	0.19
43	180732	136	70,843	0.19
44	091731	135	70,978	0.18
45	220515	133	71,111	0.18
46	110402	130	71,241	0.18
47	PIPER	130	71,371	0.18
48	180793	127	71,498	0.17
49	SAGMRE	125	71,623	0.17
50	260041	125	71,748	0.17
51	091771	123	71,871	0.17
52	091691	120	71,991	0.16
53	ONEIDA	119	72,110	0.16
54	320022	118	72,228	0.16
55	220611	111	72,339	0.15
56	220171	111	72,450	0.15
57	260293	107	72,557	0.15
58	260083	106	72,663	0.15
59	220522	106	72,769	0.15
60	030101	104	72,873	0.14
61	220301	101	72,974	0.14
62	220721	101	73,075	0.14

APPENDIX III

TABLE III-20

SUB-BASIN ACIDITY LOADING

Basin No. 24 - Sewickley Creek
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	090013	52,989	52,989	21.52
2	090011	29,172	82,161	11.85
3	220011	26,618	108,779	10.81
4	220013	22,313	131,092	9.06
5	220012	20,273	151,365	8.23
6	090031	15,700	167,055	6.38
7	090881	9,359	176,424	3.80
8	090032	8,401	184,825	3.41
9	091181	8,312	193,137	3.38
10	091182	7,895	201,032	3.21
11	090882	5,537	206,569	2.25
12	090082	4,512	211,081	1.83
13	090892	3,809	214,890	1.55
14	160033	3,773	218,663	1.53
15	090891	3,056	221,719	1.24
16	160031	3,033	224,752	1.23
17	090771	2,851	227,603	1.16
18	160032	2,524	230,127	1.03
19	090781	2,178	232,305	0.88
20	090084	1,589	233,894	0.65

APPENDIX III

TABLE III-20 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 24 - Sewickley Creek
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
21	090921	1,396	235,290	0.57
22	090083	1,240	236,530	0.50
23	090041	1,180	237,710	0.48
24	090077	1,167	238,877	0.47
25	090022	1,127	240,004	0.46
26	090071	1,115	241,119	0.45
27	190032	1,087	242,206	0.44
28	090072	1,072	243,278	0.44
29	090401	813	244,091	0.33
30	090023	668	244,759	0.27
31	090051	205	244,964	0.08
32	110021	169	245,133	0.07
33	190051	161	245,294	0.07
34	091011	152	245,446	0.06
35	090801	150	245,596	0.06
36	160161	134	245,730	0.05
37	110032	132	245,862	0.05
38	090091	121	245,983	0.05
39	190042	110	246,093	0.04
40	100017	109	246,202	0.04

APPENDIX III

TABLE III-21

SUB-BASIN ACIDITY LOADING

Basin No. 25 - Middle Youghiogheny River from West Moreland - Fayette County Line to Connelsville, Penna.

Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	092882	1,555	1,555	30.01
2	092941	800	2,435	16.99
3	093051	841	3,276	16.23
4	093251	520	3,796	10.04
5	FLOR-2	212	4,008	4.09
6	092051	199	4,207	3.84
7	092181	188	4,395	3.63
8	092901	182	4,577	3.51
9	093241	179	4,756	3.45
10	FLOR-1	155	4,911	2.99
11	092911	143	5,054	2.76
12	092891	127	5,181	2.45

APPENDIX III

TABLE III-22

SUB-BASIN ACIDITY LOADING

Basin No. 26 - Mounts Creek and Indian Creek
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	080971	16,109	16,109	41.37
2	100421	11,483	27,592	29.49
3	100422	9,656	37,248	24.80
4	100852	1,100	38,348	2.83
5	101121	147	38,495	0.38
6	100961	122	38,617	0.31
7	100441	109	38,726	0.28
8	100451	106	38,832	0.27
9	080871	103	38,935	0.26

APPENDIX III

TABLE III-23

SUB-BASIN ACIDITY LOADING

Basin No. 27 - Youghiogheny River West from Connelsville to Confluence, Penna.

Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	340801	727	727	56.31
2	080753	123	850	9.53
3	080752	115	965	8.91
4	342092	113	1,078	8.75
5	340701	111	1,189	8.60
6	340802	102	1,291	7.90

APPENDIX III

TABLE III-24

SUB-BASIN ACIDITY LOADING

Basin No. 29 - Castleman River
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	240711	2,135	2,135	6.24
2	241891	1,778	3,913	5.20
3	241671	1,731	5,644	5.06
4	020151	1,702	7,346	4.98
5	241371	1,630	8,976	4.77
6	020521	1,576	10,552	4.61
7	020142	1,557	12,109	4.55
8	020181	1,403	13,512	4.10
9	241481	1,378	14,890	4.03
10	241712	1,377	16,267	4.03
11	241741	1,255	17,522	3.67
12	240362	1,246	18,768	3.64
13	241383	1,162	19,930	3.40
14	241381	1,120	21,050	3.28
15	242051	1,108	22,158	3.24
16	242351	1,055	23,213	3.09
17	240781	1,017	24,230	2.97
18	241701	724	24,954	2.12
19	240971	703	25,657	2.06
20	242081	644	26,301	1.88
21	241711	595	26,896	1.74
22	241382	584	27,480	1.71
23	080021	444	27,924	1.30
24	080031	440	28,364	1.29
25	240361	425	28,789	1.24
26	240021	360	29,149	1.05
27	240161	322	29,471	0.94
28	240731	270	29,741	0.79
29	241301	267	30,008	0.78
30	020141	252	30,260	0.74

TABLE III-24 (Continued)

SUB-BASIN ACIDITY LOADING

Basin No. 29 - Castleman River
Ranking by Acidity — Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
31	241641	247	30,507	0.72
32	080171	213	30,720	0.62
33	241591	210	30,930	0.61
34	080041	191	31,121	0.56
35	240841	164	31,285	0.48
36	020351	157	31,442	0.46
37	241372	152	31,594	0.44
38	240741	150	31,744	0.44
39	030021	150	31,894	0.44
40	020221	147	32,041	0.43
41	240101	147	32,188	0.43
42	241661	143	32,331	0.42
43	241061	138	32,469	0.40
44	240031	136	32,605	0.40
45	240251	136	32,741	0.40
46	240631	134	32,875	0.39
47	020101	132	33,007	0.39
48	080141	129	33,136	0.38
49	240481	126	33,262	0.37
50	080182	124	33,386	0.36
51	240951	124	33,510	0.36
52	080061	120	33,630	0.35
53	240612	119	33,749	0.35
54	240872	119	33,868	0.35
55	240571	116	33,984	0.34
56	020191	105	34,089	0.31
57	020012	103	34,192	0.30

APPENDIX III

TABLE III-25

SUB-BASIN ACIDITY LOADING

Basin No. 30 - Upper Youghiogheny River above Confluence, Penna.
Ranking by Acidity Average Annual Acidity (Lbs./Day)

Rank	Mine No.	Acidic Load/Day	Cumulative	% Total
1	120091	8,723	8,723	61.22
2	120092	2,824	11,547	19.82
3	120181	975	12,522	6.84
4	560091	906	13,428	6.36
5	050121	226	13,654	1.59
6	010011	147	13,801	1.03
7	050101	122	13,923	0.86
8	110071	113	14,036	0.79
9	110101	111	14,147	0.78
10	140072	102	14,249	0.72

APPENDIX IV

DESCRIPTIVE PREAMBLES TO VOLUMES II, III & IV

VOLUME II

STANDARD MINE ANALYSIS

DESCRIPTION OF CONTENTS

Acid Mine Drainage Contamination statistics for each Standard Mine (SM) cover three pages of printout for each month. On the first page the mean, variance and standard deviation of concentration of each pollutant is presented. In addition, these same statistical measures are given for the load of each pollutant.

The numbers are in floating point format, which is a mantissa followed by an exponent. For example, the mean concentration of acidity for Sagamore in December was 3.82609E+03, or $3.82609 \times 10^3 = 3,826.09$ (milligrams per liter). Flow in this month was 1.85009E-01 or 0.185009 (liters per second). The sign and two digit number following the letter E represent the exponent. A positive exponent moves the decimal point to the right. A negative exponent moves the decimal point to the left. The number of places the decimal point is moved is indicated by the exponent.

The second page displays covariance and correlation coefficients of concentration. There is a pair of lines for each pollutant listed in the left most column. The first line of each pair is covariance and the second line is the correlation coefficient. Each column represents the other pollutant in the correlation pair.

The third page of each set is the same as the second page except that it presents covariance and correlation coefficients of load instead of concentration of pollutant.

DESCRIPTION OF PRINTOUT

Between the sets of statistical information as described above, are rectangular shaped sets of data printouts. The significance of this is that all of the raw data are presented here for each of the standard mines, and it is not required to refer to the original source material. A description of the manner in which the data should be read follows.

VOLUME II

DESCRIPTION OF PRINTOUT

Position	Data for Named Mines	Data for Numbered Mines
1 - 8	Mine Name	Mine Number
9 - 14	Date of Sample	Date of Sample
15 - 20	Blank	15 - 18 Time of Day 19 - 20 Temperature °C
21 - 27	Flow in gals. per day No decimal point in field for named mines	Flow in cfs Decimal point between 24 & 25
28 - 30	pH in pH units Decimal point between 28 & 29	pH in pH units Decimal point between 29 & 30
31 - 35	Acidity in mg/l Decimal point between 34 & 35	Acidity in mg/l Decimal point between 34 & 35
36 - 40	Total Iron in mg/l Decimal point between 38 & 39	Total Iron in mg/l Decimal point between 38 & 39
41 - 45	SO_3 for named mines in mg/l Decimal point between 44 & 45	Sulfate (SO_4) in mg/l Decimal point between 44 & 45
46 - 49	Hardness in mg/l Always zero for named mines	Hardness in mg/l No decimal point in field
50 - 53	Blank	Specific conductance in micro mhos at 25°C
54 - 56	Dissolved oxygen in mg/l Always zero for named mines	Dissolved oxygen in mg/l

Position	Data for Named Mines	Data for Numbered Mines
57 - 60	Alkalinity in mg/l Always zero for named mines	Alkalinity in mg/l No decimal point in the field
61 - 64	Blank	Blank
68 - 69	Iron in mg/l Decimal point between 68 & 69	Iron in mg/l Decimal point between 68 & 69
70 - 74	Chloride in mg/l Always zero for named mines	Chloride in mg/l Decimal point between 73 & 74
75 - 78	Aluminum in mg/l Always zero for named mines	Aluminum in mg/l Decimal point between 77 & 78

VOLUME III

SYNTHESIZED NSS TIME-LOAD PROFILES

DESCRIPTION OF CONTENTS

SUMMARY

Volume III presents the results of the NSS time-load profile synthesizing process. This process first determines which of the SM time-load vectors most closely resembles that of each pollutant for each NSS, and then proceeds to generate time-load profiles covering an entire year for each pollutant and NSS.

DESCRIPTION OF PRINTOUT

In the first line of each page are the 6 digit NSS mine identification and minor basin numbers. The left column contains the NSS pollutant and directly under the pollutant is the SM that had the best time-load vector match. The next twelve columns are the loads in pounds per day, by month. The monthly load values are in floating point format. Numbers of this type are represented by a mantissa and exponent. This is best described by example:

$2.984E+02 = 2.984 \times 10^{2} = 298.4$

$1.234E-01 = 1.234 \times 10^{-1} = 0.1234$

The plus or minus sign following the E indicates whether the actual decimal point should be moved to the right (plus) or the left (minus). The number following the sign tells how many positions to move the decimal point.

The last data on each page is a group of one or more lines. Each line represents a sampling of the NSS at a point in time. Letting the first number of each line be in position one, the following describes the data. All of the lines, taken together, represent all of the raw data for each discharge in the Monongahela Basin, except SM's which are presented.

VOLUME III

DESCRIPTION OF PRINTOUT

Position	Data
1 - 2	State Code (23 MD, 41 PA, 55 W VA)
4 - 5	Minor Basin
7 - 12	Mine identification number
14 - 23	Flow in cubic feet per second Decimal point between 19 & 20
25 - 27	pH
29 - 30	Temperature °C, recorded in the field
32 - 35	Conductivity, micromhos at 25°C
37 - 39	Laboratory pH
41 - 44	Acidity, mg/l as $CaCO_3$
46 - 48	Alkalinity, mg/l as $CaCO_3$
50 - 53	Hardness, EDTA, mg/l as $CaCO_3$
55 - 58	Total Iron, mg/l Decimal point between 57 & 58
60 - 63	Sulfate, mg/l
65 - 68	Aluminum, mg/l Decimal point between 67 & 68
70 - 75	Date

Data validity codes for the immediately preceeding data are coded in positions: 13, 24, 28, 31, 36, 40, 45, 49, 54, 59, 64, and 69.

Validity Codes:

1 - true datum

2 - irrelevant datum

3 - true value, datum x 10

4 - true value, datum x 100

Any NSS that had zero flow was not processed.

VOLUME IV

SOURCE RANKING BY ACIDITY LOAD

DESCRIPTION OF CONTENTS

The Source Ranking by Acidity Load Report is a listing of AMDC Sources segregated by subbasin and cyclical month within each subbasin. All active AMDC sources within each subbasin are listed which have average acid load greater than 1 lb/day for the month in question. Within each month and subbasin the sources are ranked in the order of their acid load contribution. All values are given in pounds per day.

The subbasin and cyclical month are shown at the top of each page of the report. The ranking order of the sources is shown in the left-most column of each page of the report. The sources are identified in the next column to the right. The succeeding columns to the right show the loads of the various pollutants, starting with acidity, in lbs/day. The left column of the two shows individual source load, while the column to the right is the load of the pollutant accumulated over the indicated month and basin.